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PRENATAL DEVELOPMENT of farm animals, with the exception of the pig, has received very little attention. A more complete knowledge of this phase of the animal's existence is desirable not only to study the normal variations in development but also to establish a foundation for the study of factors causing significant deviations from normal development. Before the effects of nutrition or inheritance on the production of abnormal, dead, or weakened young can be completely understood, a standard of development, i.e., the "normal," must be established. Otherwise it might be difficult to determine the amount, kind, manner, or importance of the change under consideration.

From an economic standpoint, meat animals raised for market purposes spend a large proportion of their lives **in utero;** this period may account for nearly one third or one half of the total life of the individual. If more were known about the prenatal phase of their existence, perhaps some of the problems that arise during the animals' later life could be explained more easily.

The objects of this experiment were:

1. To trace the normal prenatal development of the bovine by use of specimens of known age.
2. To establish a standard to be used when studying factors responsible for variations in prenatal development.

REVIEW OF LITERATURE

A few embryos and fetuses of farm animals of definite or approximately known ages have been recovered, and the statistics of their body measurements have been reported in connection with studies of prenatal growth. The number of published illustrations of specimens of known ages is very limited, particularly in the case of the bovine. Hartman et al. (10) and Miller et al. (13) both described a two-cell cow egg which was recovered 48 hours after mating and an unfertilized tubal ovum found 72 hours after mating. Kupfer (12) found that four days were necessary for the ovum to reach the uterine horn. He also reported a series of specimens ranging in age from "about 3 weeks" to "between 15-17 weeks." The ages of Kupfer's speci-

mens were approximate, i.e., "about 3 weeks," "a little older than 3 weeks," "not quite 4 weeks." When the probable ages of Kupfer's embryos were considered, the stage of development for a given age agreed quite closely with specimens presented later. Hammond (9) briefly described and illustrated a few specimens which he recovered at the end of each lunar month of pregnancy.

EXPERIMENTAL PROCEDURES

Animals Used

The ova and most embryos were recovered from a group of grade beef heifers. The remaining embryos and all fetuses were recovered from grade cows of mixed breeding. Any possible effects of past history or breed of the females on the recovered specimens will be discussed later.

Basis for Determining the Age

The cattle were closely watched for signs of estrus, and cows that were in heat during the day were mated by natural service. The period of estrum is short in cattle and ovulation in the cow occurs within the first day after the cessation of heat (Brewster, May, and Cole [3]). Brewster et al. loc. cit. found that six to nine hours were necessary for the sperm to reach the infundibulum. Even though the cows were mated near the end of estrum, the sperm were undoubtedly at the infundibulum when the ova were released. Therefore, the main variable in determining the actual age of the egg, embryo, or fetus was the actual time of ovulation. Since nearly all the cows passed from heat during the night or very early the next morning, the ages of the specimens were timed from 6:00 p.m. of the day the cow was mated until the time of slaughter. This method of determining age furnished as nearly a uniform base as the authors were able to provide. The ages are reported in days and the nearest hour except for the older fetuses which are reported to the nearest day.

Technics Used

The animals were slaughtered at the University and the reproductive tracts were removed to the laboratory as soon as possible. The ova and blastocysts were recovered, photographed, and measured in the manner described by Clark (4). Both the ova and blastocysts were fixed in Bouin's fluid, sectioned by use

of the technic given by Green, Barrett, and Winters (5), and stained with Heidenhain's iron-hematoxylin. Blastocysts were counterstained with eosin.

All older embryos were recovered by dissection of the uterus under Locke's physiological saline solution. After recovery, they were transferred to a second dish containing Locke's solution, and there the embryonic membranes were removed from the specimens prior to photography; however, the amnion was not removed from specimens under 20 days of age. The belly stalk of larger embryos was ligated before cutting to prevent loss of blood from the umbilicus. The specimens were photographed while still in saline and before fixation. They were then fixed in Bouin's fluid, dehydrated with alcohol, cleared in cedarwood oil, infiltrated with paraffin, serially sectioned at 10-15μ, stained with Heidenhain's iron-hematoxylin, and counterstained with eosin. All of the reagents used were prepared according to Guyer (8).

The fetal specimens up to 230 days of age were immersed in water at the time of photography. Those which were covered with hair were wiped dry before being photographed. The fetus was then measured and later taken to the X-ray laboratory. The X-ray negatives were not large enough to accommodate the larger specimens **in toto;** this gave rise to a series of illustrations for some individual specimens. Variation in magnification of different views of the same fetus was made in order to insure as much detail as possible. Photographic negatives were made from the X-ray pictures in order to bring out some of the structures which were rather faint on the X-ray negatives. Photographic positives were then made.

Measurements

A number of body measurements were secured in the manner described by Winters and Feuffel (16). They were weight, forehead-rump length, shoulder point to pin bone, chest circumference, abdomen circumference, foreleg circumference, horizontal head circumference, head breadth, forearm length, hock to hoof point, and tail length. Other measurements taken were:

1. **Crown-rump length**—This was secured by measuring the distance from the crown of the head to the rump. It was taken from the photograph and a correction was made for magnification. The greatest length and contour lengths were secured from the pictures in a similar manner.

2. **Greatest length**—The greatest total length of the embryo regardless of definite anatomical locations was measured.

3. **Contour length**—The contour length was taken by measuring the length of thread necessary to follow the body outline from the tip of the nose, or equivalent, over the head, back, and to the posterior tip of the body (tail included).

4. **Hind leg circumference**—The point of measurement was half way between the hock and first pastern joint.

5. **Head length**—This included the distance from the chin to the top of the head.

6. **Face height, total**—The distance from the chin to a line joining the inner corners of the eyes was determined.

7. **Face height, upper**—This was the distance from the muzzle to a line joining the inner corners of the eyes.

8. **Face breadth**—The breadth of the face was taken at a line drawn just below the inner corners of the two eyes.

Numbering Systems

The figure number assigned to the picture of a whole specimen is a whole number (e.g., Fig. 6, Fig. 43, etc.). A whole number followed by a small case letter indicates a histological section of the specimen indicated by the whole number. For example, figure 38a is a section of the 40-day-old specimen shown in figure 38. Some sections are illustrated for which the picture of the intact specimen is not shown. For example, whole ova are shown in figures 4 and 6. A section of a third egg is shown in figure 5a although no whole ovum picture is shown of the egg from which the section in figure 5a was secured. As a result, no figure 5 exists. In the X-ray series, a figure in the position of an exponent figure (^{1} or ^{2}) refers to a side or dorsal view, respectively (e.g., Fig. 44^1). A small case letter following a figure so placed (^{1a}) refers to one of a group of that particular view.

For all embryos in figures 28-38, inclusive, the number accompanying each embryonic section indicates the serial order of the section under consideration. In all but one instance, noted below, the numbering begins from the most cephalic section.

DESCRIPTION AND DISCUSSION OF SPECIMENS

Gametogenesis

The bovine comes into sexual maturity when 12-18 months of age. The main factors influencing the time of puberty are breed and state of nutrition. In the female, estrum reoccurs about every 19 days throughout the year. The male produces sperm and will mate at any season.

All stages of spermatogenesis and spermiogenesis are illustrated in figures 1a and 1b. These stages do not differ essentially from those of other mammals. Bull sperm (Fig. 2) have a slightly more "pear" shaped head than sheep sperm. The head of the sheep sperm is broader and slightly more rectangular at the base (Green and Winters [6]). Figure 3 is a cross section of a ripe bovine follicle.

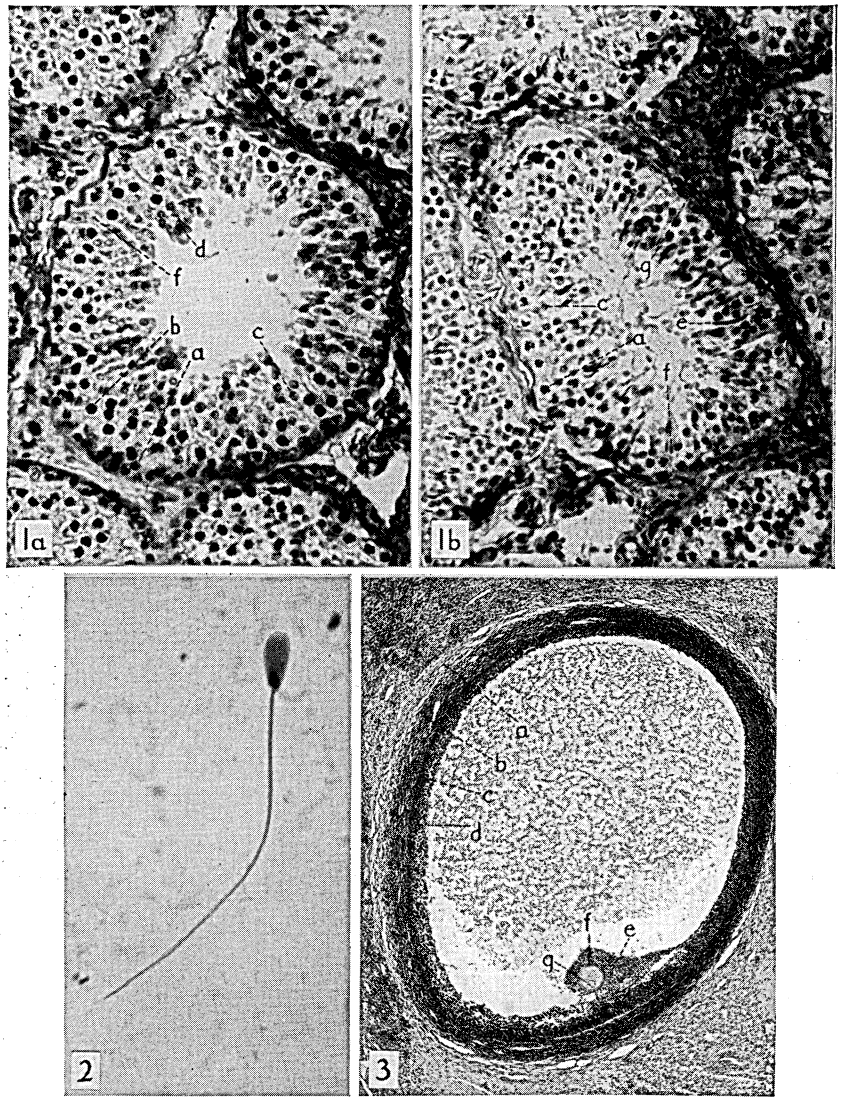
Division of Prenatal Periods

The growth of the individual from the formation of the zygote until birth is a continuous process; however, the prenatal period can be divided into certain phases of development without altering the basic concept of continuity. These phases can be designated according to the size of the individual as measured by length, volume, weight, or a combination of these measures. They may also be designated according to the growth or development of either tissues or organs or the individual as a whole. The development of the individual as a whole may be measured by the appearance of the specimen because appearance is, of necessity, a reflection of growth processes. The prenatal period is usually divided into three major periods, namely: ovum, embryonic, and fetal, based upon some of the more critical moments in the individual's life as well as upon the amount of development.

Little change can be noted in the shape or size of the ovum until the zona pellucida is shed even though much cellular activity has taken place. After the zona is shed, the embryo enlarges but retains an approximately spherical form. Because of the similarity of the growth changes up to the time of attachment, the period from fertilization until implantation or attachment is usually known as the period of the ovum.

The embryonic period is usually considered as the time during which the major tissues, organs, and their systems are formed. While most of these alterations are internal, at the same time the body shape of the individual undergoes a series of successive changes. For example, the body torsion characteristic of the 22-day embryo is lost and the specimen assumes a rather smooth C shape by 26 days of age and, at 30 days, the curved shape has been altered by the appearance of rather definite points of flexure. These and other changes in body shape make it possible to describe embryonic development not only in terms of linear measurement but also in terms of body outline.

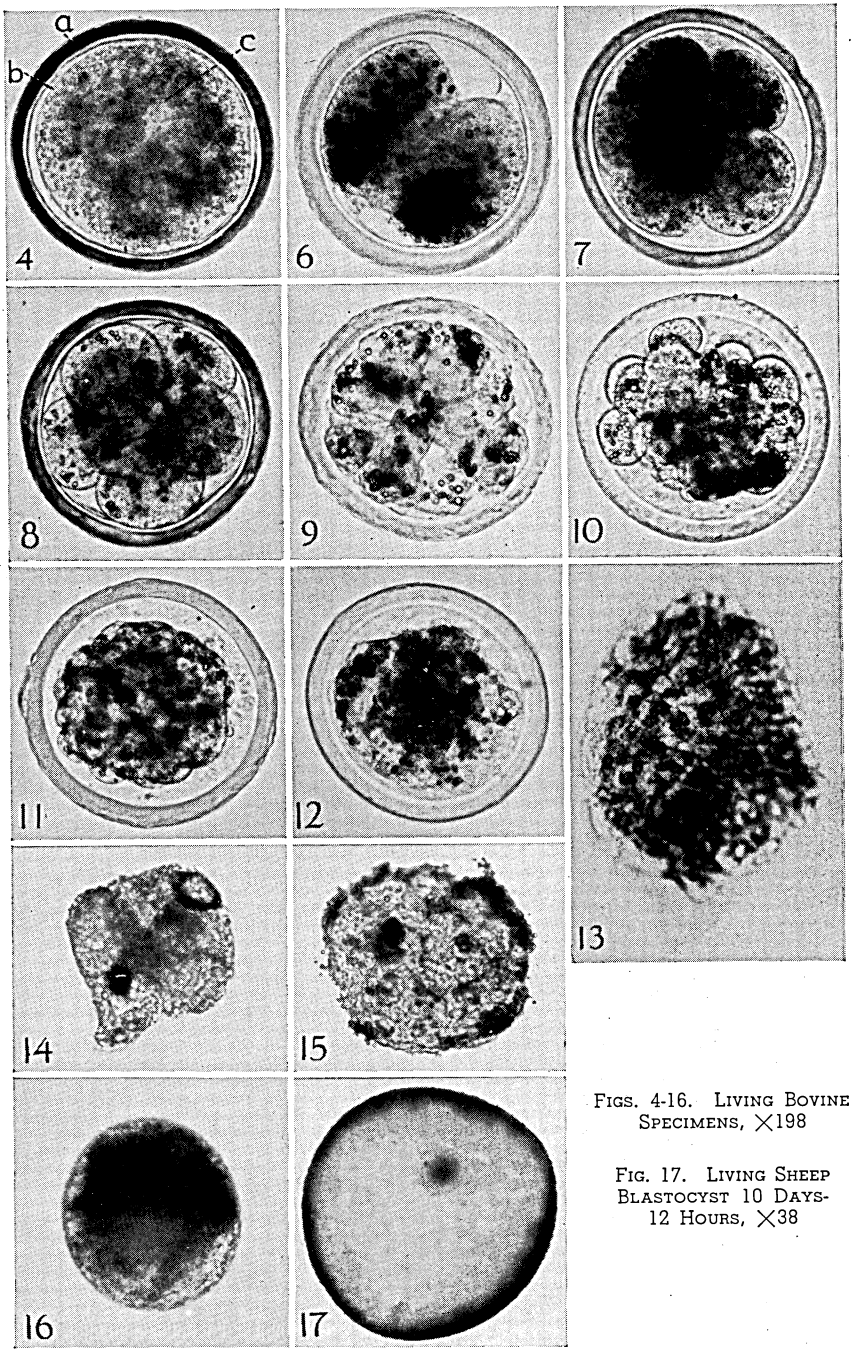
Because the internal organs are quite well formed by the end of the embryonic period, the main changes experienced by the



FIGS. 1a-1b. CROSS SECTION BULL TESTES. BOUIN'S FIXATIVE, HEIDENHAIN'S IRON-HEMATOXYLIN STAIN, 5μ. FIGURE 1a, ×170, FIGURE 1b, ×184. (a) SPERMATOGONIUM, (b) PRIMARY SPERMATOCYTE, (c) SECONDARY SPERMATOCYTE, (d) SPERMATID, (e) SPERM CELL, (f) SERTOLI CELL, (g) INTERSTITIAL CELL

FIG. 2. BOVINE SPERM CELL, ×828

FIG. 3. CROSS SECTION OF RIPE BOVINE FOLLICLE, ×16. FIXATIVE AND STAINING SAME AS FIGURE 1. (a) TUNICA EXTERNA, (b) TUNICA INTERNA, (c) MEMBRANA PROPRIA, (d) STRATUM GRANULOSUM, (e) CUMULUS OOPHORUS, (f) OVUM, (g) NUCLEUS



FIGS. 4-16. LIVING BOVINE SPECIMENS, ×198

FIG. 17. LIVING SHEEP BLASTOCYST 10 DAYS-12 HOURS, ×38

FIG. 4. 1 DAY-14 HOURS; FIG. 6, 2 DAYS-2 HOURS; FIG. 7, 2 DAYS-14 HOURS; FIG. 8, 2 DAYS-16 HOURS; FIG. 9, 4 DAYS-14 HOURS; FIG. 10, 5 DAYS-14 HOURS; FIGS. 11 AND 12, 7 DAYS-14 HOURS; FIG. 13, 8 DAYS-14 HOURS; FIG. 14, 9 DAYS-19 HOURS; FIG. 15, 10 DAYS-15 HOURS; FIG. 16, 11 DAYS-20 HOURS

(a) Zona Pellucida, (b) Vitelline Membrane, (c) Cytoplasm

individual during the next, or fetal, stage are those of growth and minor details of differentiation. The designation of the time of division between the embryonic and fetal periods is somewhat arbitrary; however, the authors have termed the ages from 45 days to the end of gestation, inclusive, as the fetal period largely because all body organs are rather well differentiated at 45 days.

Period of the Ovum

A freshly ovulated egg, 1 day-14 hours old, is shown in figure 4. It was photographed while in normal saline as were all of the ovum specimens. Two sperm were observed on the outside of the zona pellucida and the egg probably had been fertilized shortly before recovery.

During the second day, formation and division of the blastomeres apparently goes on at a rapid rate. Two-celled eggs were recovered at 2 days-2 hours (Fig. 6) and 2 days-12 hours (not illustrated). Six blastomeres were present at 2 days-14 hours (Fig. 7) and figure 8 illustrates an eight-celled ovum which was only 2 days-16 hours old.

The earliest uterine egg found in this study was the 4 day-14 hour specimen shown in figure 9. It was in the 16-cell stage. The 32-cell stage was recovered at 5 days-14 hours (Fig. 10).

Two eggs were recovered at an age of 7 days-14 hours (Figs. 11 and 12). These were secured from separate females; however, both were in the same stage of development. The blastocoele appeared to be forming in each, and in both cases it was more apparent in the fresh specimens than in photographs of either the living or sectioned eggs. The zonas were both ready to fragment and break from the egg (blastula) proper. Each was sectioned and stained with greater difficulty than was characteristic of the younger ova.

The zona pellucida was not present on the blastula recovered at an age of 8 days-14 hours (Fig. 13). This stage in the bovine was much more difficult to recover and photograph than that of the sheep. It appeared to contain considerable yellow pigment, which made recognition extremely difficult.

The blastocyst shown in figure 13 appears much larger than some of the succeeding specimens, although it was younger than the following stages. At this period of development, the blastocysts were very fragile and the size of the specimen at the time of photography depended to some extent upon the length of time elapsing from time of recovery to photography, temperature of the saline during recovery, the amount of heat absorbed by the

saline during photography, and the intensity of the light during photography. These factors, however, do not account for all the differences in size between the sheep and bovine specimens.

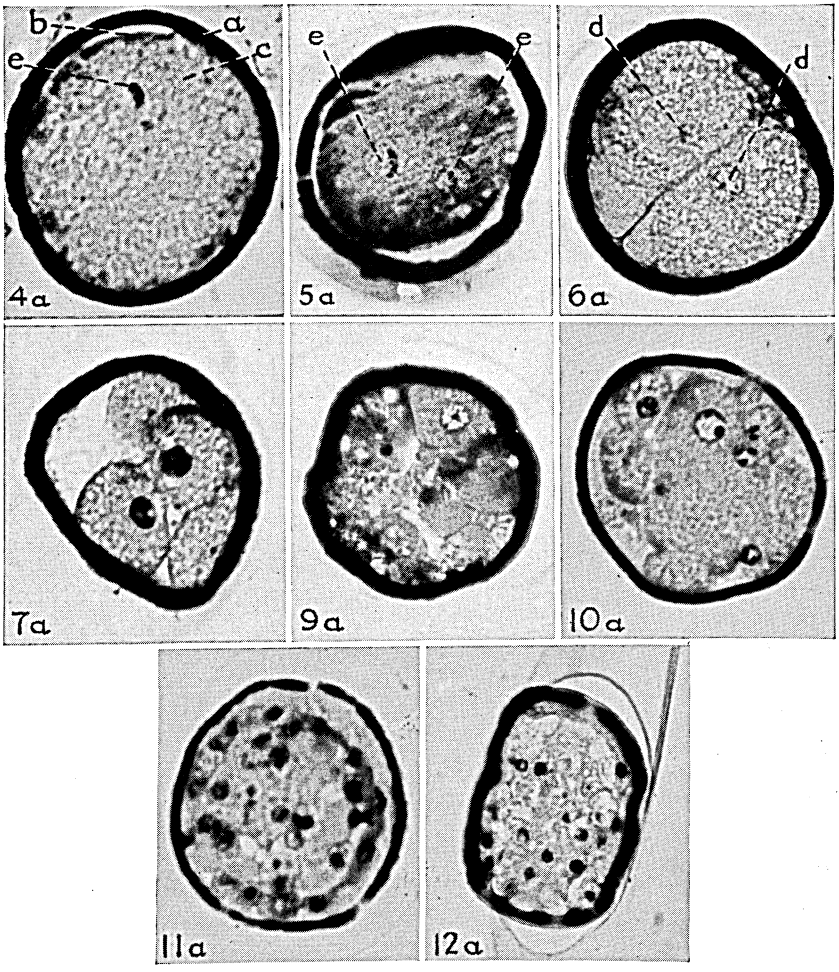
The specimen illustrated in figure 14 was recovered when 9 days-19 hours old. It was photographed after fixation in alcohol. The germ disc was plainly visible at this time.

Figure 15 illustrates a 10 day-15 hour old blastocyst. The next specimen (Fig. 16) is a blastocyst recovered after 11 days-20 hours. Although it was flushed from the uterus, it may have been in the early stages of implantation.

The early ovum stages of the bovine are about one day older than similar stages in the sheep (see Clark [4]). These differences both in the time of segmentation and the rate of tubal journey may be accounted for by the variation in the time of ovulation between the two species. The sheep ovulates approximately at the end of estrus and the cow within 24 hours after that time. Near the time of implantation, differences in the rate of development may be found. These differences are, however, more pronounced during the embryonic period than at implantation time. Figure 17 illustrates a 10 day-12 hour sheep blastocyst. It was recovered by dissection rather than flushing and was found in the process of becoming attached to the wall of the uterus. In comparison with a bovine blastocyst of the same age (Fig. 16), the trophoblast of the sheep is much larger (note magnification of the two figures); the germ disc area is more pronounced; and the blastocyst's shape indicates that the elongation of the trophoblast is about to start. This occurs in the bovine a day or two later.

Sectioned ova—All of the ova which were recovered for the above study were sectioned and eggs typical of the various stages are shown in figures 4a to 12a. Figure 5a was included to show the two pronuclei. A whole mount picture of this egg was not included in the live ovum group.

Abnormal ova—The females used for the recovery of the segmentation specimens discussed in this paper as well as some of the older embryos were selected from young animals that had been used for a feeding trial the previous winter. They were all quite fat—similar in condition to animals fitted for the show ring. They would have graded "prime" at any livestock market. At the time some of them were mated they were in their first or second estrus periods. From these matings a relatively large proportion of apparently abnormal eggs were recovered. Winters (15) illustrated one of these ova. The zona was both actually and relatively thicker than usual and the egg itself was smaller than the

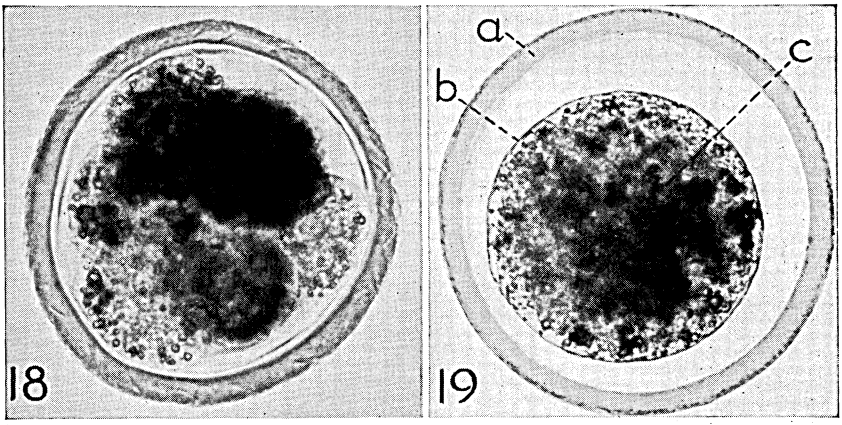


FIGS. 4a-12a. SECTIONED BOVINE OVA, ×343
(a) Zona Pellucida, (b) Vitelline membrane, (c) Cytoplasm, (d) Nucleus, (e) Pronuclei

Figs. 4a, 6a-12a are of the same age as the photographs of living specimens bearing the same number. Fig. 5a was 0 day-23 hours old

normal. Two of the ova (not illustrated) fragmented completely when placed into 70 per cent alcohol. One of these was a single-celled egg recovered at an age of 2 days-17 hours and the other had approximately 32 cells at an age of 6 days-14 hours.

The ovum illustrated in figure 18 was recovered at 3 days-14 hours and apparently was in a six-cell stage. The deeper color and retarded development indicated that the egg was undergoing degeneration at the time of recovery. An unfertilized egg is



FIGS. 18-19. PATHOLOGICAL OVA, AGE 3 DAYS-14 HOURS, ×294
(a) Zona Pellucida, (b) Vitelline Membrane, (c) Cytoplasm

shown in figure 19. It was 3 days-14 hours old. The heifer had been bred but even if fertilization had taken place, no development occurred. The cytoplasm was shrunken and the ovum appeared in the early stages of disintegration. Another dead egg was recovered at an age of 9 days-17 hours. It had developed only a few blastomeres and then died.

The recovery of this relatively large proportion of abnormal eggs from these heifers bred during their first or second heat period helps to explain observed "sterility" encountered in young females. This condition is likewise met rather frequently in species other than the bovine. Ashley-Montagu (2) has rather recently reviewed much of the data presented on "adolescent" sterility. The partial development of ova and embryos and their premature death may account for some of the irregularities observed in the length of estrus cycles and the return of estrum after one or two "skipped" periods. On the other hand these eggs that partially segment and cease development may be carrying lethal factors that prevent complete growth. The nutritional state of the females might have been partially responsible for the number of abnormal ova although the number of abnormal eggs produced by females of a similar age but of a lower degree of finish has not been ascertained.

Embryonic Period

The embryonic period begins at the time the embryo attaches itself to the wall of the uterus. In the bovine the embryo does not appear to erode the uterine wall and "implant" itself within

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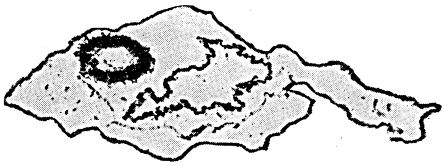

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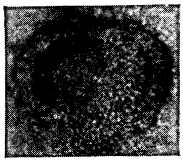

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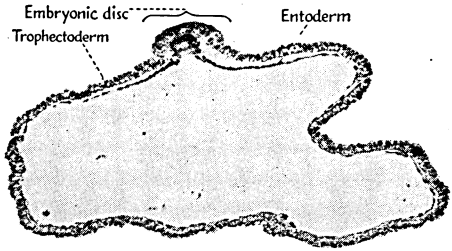

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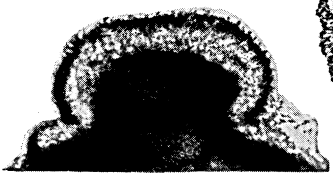

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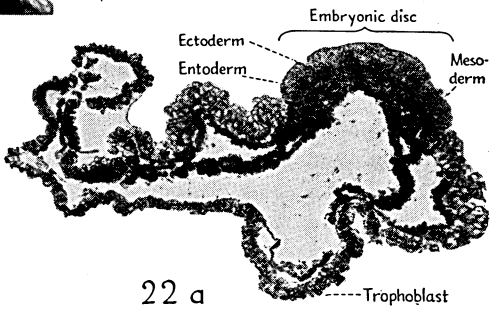

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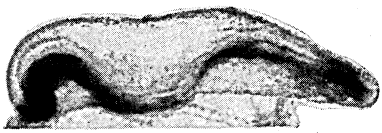

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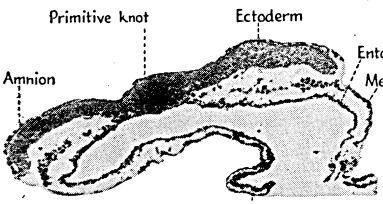

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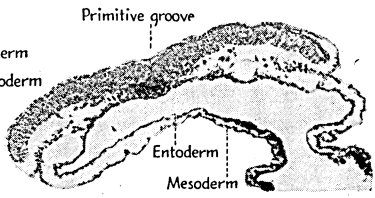


26 b

FIG. 20, 12 DAYS-15 HOURS, ×8; FIG. 20a, ×68; FIG. 21, 13 DAYS-14 HOURS, ×70; FIG. 21a, ×72; FIG. 22, 14 DAYS-14 HOURS, ×46; FIG. 22a, ×98; FIG. 23, 16 DAYS-14 HOURS, ×39; FIG. 24, 17 DAYS-14 HOURS, ×27; FIG. 25, 19 DAYS-14 HOURS, ×18; FIG. 26a, 18 DAYS-15 HOURS, ×58; FIG. 26b, 18 DAYS-15 HOURS, ×58

the uterine wall as does the human embryo. It seems to make a surface to surface contact as it does in the sheep and rabbit.

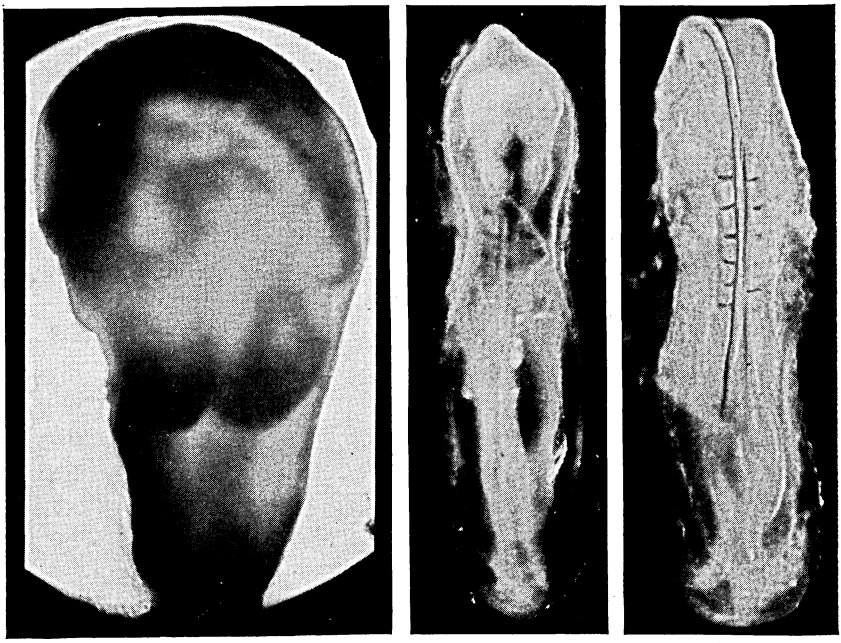
The specimen in figure 20 was 12 days-15 hours old and was recovered by flushing the uterus with saline. The chorion which was in the first stages of elongation measured 4.1 mm. x 1.65 mm. The embryo was probably loosely attached to the wall of the uterus since Clark (4) reported the comparable stage in sheep to be attached, and Winters (unpublished data) has recovered, by dissection, sheep and rabbit trophoblasts of spherical form that were attached. Such an early attachment could easily be broken by flushing. The entoderm was well developed and can be seen in section in figure 20a.

The next embryo (Fig. 21) was 13 days-14 hours old. The chorion was 8 mm. long and the germ disc measured 0.398 mm. x 0.214 mm. This specimen was recovered by dissection and was lightly attached to the uterine wall. The chorion was very fragile and could not be removed intact. The germ disc area was completely elevated to the surface and no trophoblastic cells were covering the area (Fig. 21a). The entoderm had completely lined the trophoblast.

Figure 22 illustrates a 14 day-14 hour embryo. The chorion extended throughout two thirds the length of the uterine horn. The amount of mesoderm formation can be seen not only in the photograph of the whole specimen but also in the section shown in figure 22a. It extended about halfway around the extra embryonic tissue and the split mesodermal layers were associating themselves with the trophectoderm and entoderm to form the extra-embryonic somatopleure, splanchnopleure, and coelom. The germ disc area was also very well defined.

The 16 day-14 hour old embryo shown in figure 23 was but slightly more advanced than the one shown in figure 22. The chorion extended throughout approximately two thirds the length of the uterine horn. The constriction of the tissue toward the future body stalk area was, however, more noticeable. The next specimen (Fig. 24) which was 17 days-14 hours old was not greatly different from the two preceding ones. Both the embryo and chorion had grown in length; the latter extended throughout the entire right horn of the uterus.

Figure 25 is a lateral view of a 19 day-14 hour embryo illustrating the head fold and general contour of the embryo. The chorion extended through the entire right horn and was starting into the left horn of the uterus. (Note: the uterine horns are about 15 inches long in the cow.)



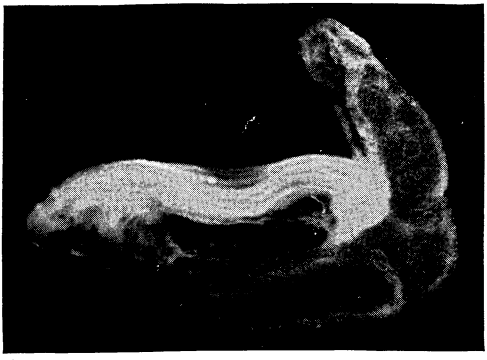


FIG. 27A, 18 DAYS-19 HOURS, ×37; 27B, 19 DAYS-19 HOURS, ×21; 27C, 20 DAYS-14 HOURS, ×17; FIG. 28, 22 DAYS-16 HOURS, ×9

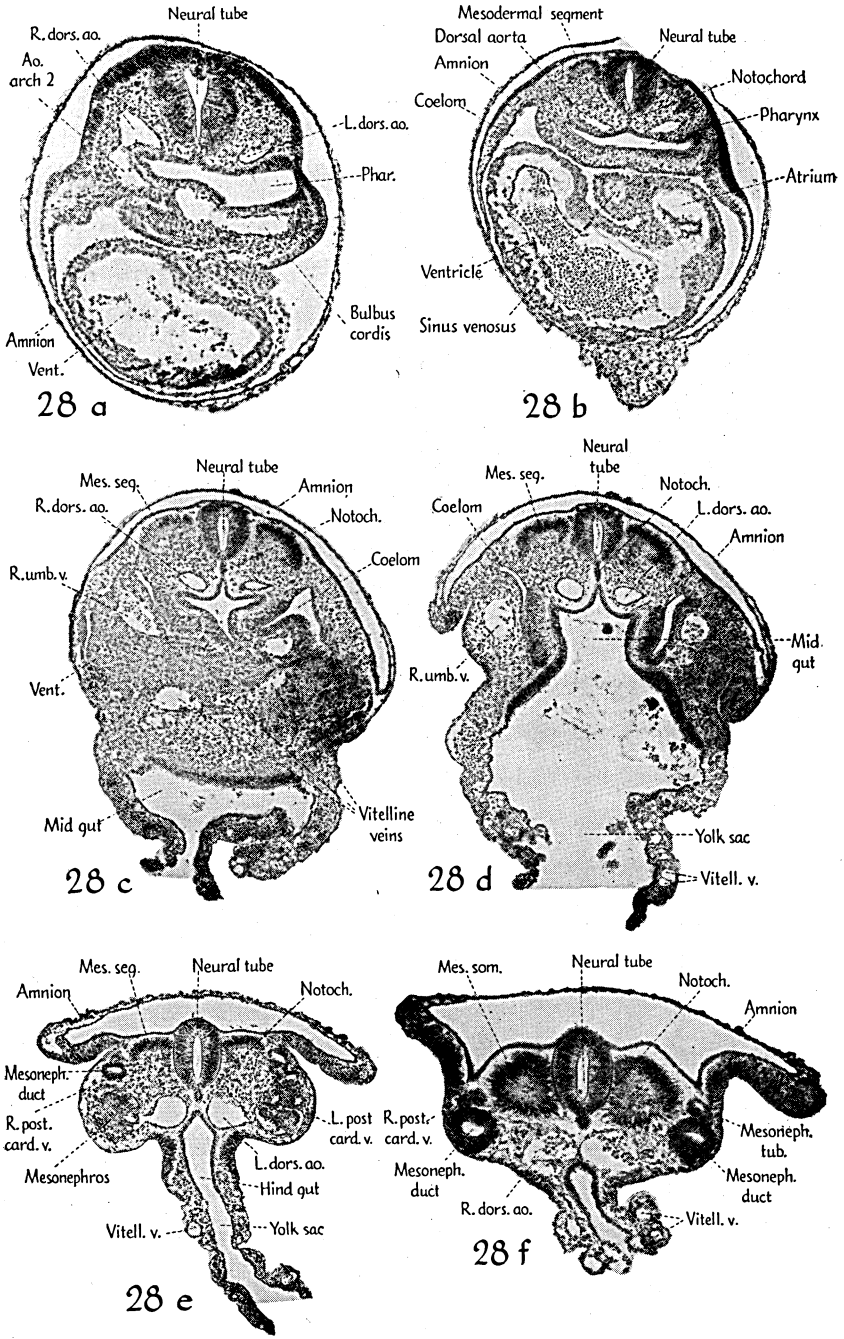
Figures 26a and 26b illustrate sections through the primitive knot and primitive groove areas of an 18 day-15 hour old embryo, essentially the same age as the specimen shown in figure 27A. These pictures may be compared for orientation purposes.

The series in figures 27A, 27B, and 27C illustrate the development of the neural regions in embryos of 18 days-19 hours, 19 days-19 hours, and 20 days-14 hours, respectively. In the embryo

shown in figure 27A, the ectodermal plate was visible as well as the early neural folds and neural groove. No somites were to be found in this specimen. A further differentiation of the neural region was found in the 19 day-19 hour embryo (Fig. 27B). The ectodermal plate and neural folds were more definitely developed in the cephalic region and the neural folds had closed together in the mid-region. The sinus rhomboidalis could be seen to better advantage in the fresh specimen than it could in the photograph. This embryo (Fig. 27B) was only 5 hours older than the one shown in figure 25. No somites were visible in the figure 25 specimen; but five somites were present in figure 27B. While the difference in age might account for a part of the variation in body structure, these embryos illustrate the difference in development that may be found in embryos of similar ages and also indicate that once somites begin to appear, they form at a rapid rate. Figure 27C shows an eight-somite embryo, 20 days-14 hours old. The neural folds in the future brain region were very distinct as was the sinus rhomboidalis. The notochord was well developed as seen in the sectioned specimen (not shown).

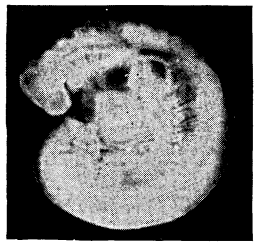
The embryo in figure 28 was 22 days-16 hours old. The neural canal was closed completely and 18 or 19 somites were present. The following features were of special note: the torsion characteristic of this stage was plainly visible; the cephalic region was definitely outlined; the first branchial arch, optic vesicles, and otic vesicles had appeared; the heart prominence was distinct; and the yolk sac (cut away) had developed. In addition, the allantois was prominent. This specimen was comparable to a 17-day sheep embryo (Winters [15]).

The whole embryo including the allantois was sectioned and 475 sections were secured. Figure 28a illustrates section No. 37 of the embryo. It passes through the region of the first branchial arch and upper heart. The bulbus and ventricle may be seen as well as the two dorsal aortae and first aortic arch loop. Figure 28b, section No. 61, shows the structures of the lower heart region and also the attachment of the amnion to the belly side of the embryo. Section No. 91 (Fig. 28c) was taken from the mid-gut region at the anterior portion of the yolk stalk. Both umbilical and vitelline veins are shown. Figure 28d, section No. 109, illustrates the mid-gut and mid-yolk stalk areas. The next section, No. 173 (Fig. 28e), was cut in the region of the hind gut. The post cardinal veins, mesonephros, and mesonephric ducts appear in this section. The last figure (Fig. 28f, section No. 327) illustrates a section taken from the region caudal to the mesonephros.

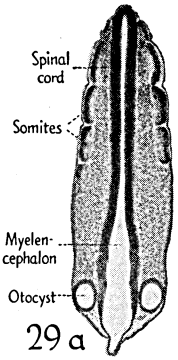


FIGS. 28a*, ×60; 28b, ×55; 28c, ×55; 28d, ×55; 28e, ×41; 28f ×62

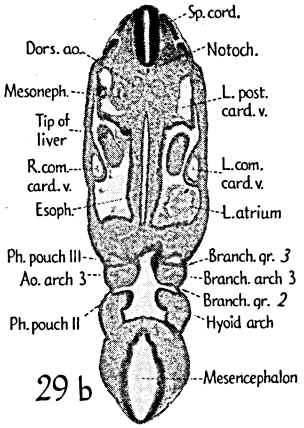
* Explanation of the abbreviations appears in the appendix.



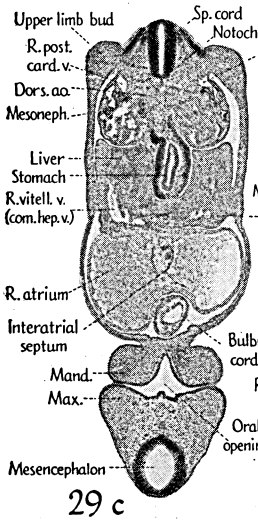
29



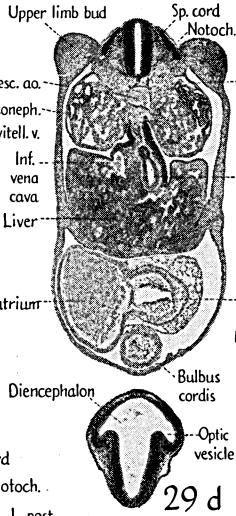
29 a



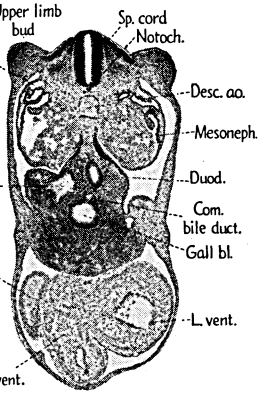
29 b



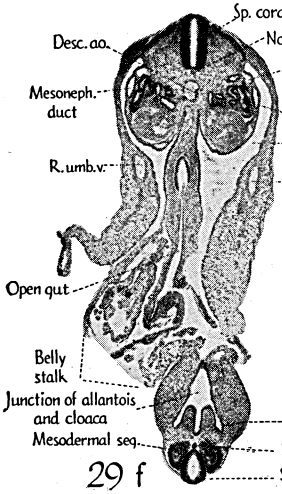
29 c



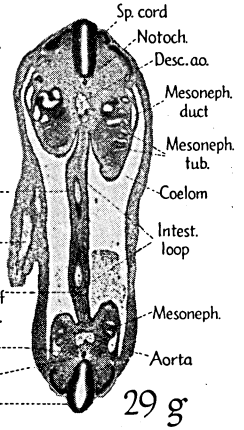
29 d



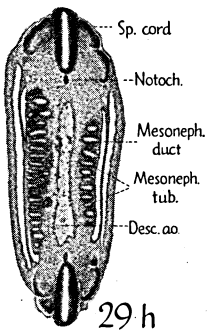
29 e



29 f



29 g



29 h

FIG. 29, 26 DAYS-2 HOURS, ×6.6; FIGS. 29a-29h, ×18

The embryo shown in figure 29 was 26 days-2 hours old. Externally, the body form had changed from the flexion and torsion characteristic of younger embryos to a C shape which was accentuated by the cephalic flexure and tail curvature. The optic vesicles were quite prominent as were the three branchial clefts and their accompanying arches. The otocysts, heart, liver, and mesonephric regions were rather distinct. All of the somites were formed and the anterior limb buds had made their appearance.

The embryo was sectioned and 294 sections were secured. Photomicrographs of representative areas are reproduced in figures 29a-h. Figure 29a, section No. 35, illustrates the region of the cephalic end of the spinal cord, myelencephalon, and otocyst. The next section, No. 76 (Fig. 29b), was taken through the pharyngoesophageal region. Figures 29c, d, and e, sections No. 95, 114, and 132, represent areas of the three anterior chambers of the brain and structures near the heart and anterior limb buds of the body trunk. Figure 29f, section No. 201, was taken from the belly stalk-cloacal regions while the remaining illustrations, figures 29g and h, sections No. 246 and 254, illustrate the structures closer to the lumbo-sacral flexure portion of the embryo.

Longitudinal sections of an embryo, essentially the same age as the one in figure 29, are shown in figures 30a and 30b. The specimen was secured from a slaughter house and its approximate age, 26 days, was determined by body measurements, appearance, and weight. A sagittal section from the right side is shown in figure 30a. The mesonephros was quite extensive at this time. The other section (Fig. 30b) was selected from a more medial plane and illustrates the relationship of the various gastrointestinal structures.

The specimen illustrated in figure 31 was 26 days-15 hours old and was essentially the same as the 26 day-2 hour embryo shown in figure 29. The chief differences between the two embryos were the presence of the fourth branchial arch, a slightly less prominent heart bulge, a larger mesonephric prominence, and slightly more differentiation in the head region of the older specimen.

A 27 day-14 hour embryo is illustrated in figure 32. It weighed 90 mg. and had a crown-rump length of 0.826 cm. Externally, a much more advanced state of body organization is evident and the rear limb buds are more easily discernible than in the previous specimen. When the embryo was sectioned, a total of 524 sections were secured. Figures 32a and b, sections No. 48 and 115, represent areas of the cephalic region. The first was taken through the region of the myelencephalon and the second through

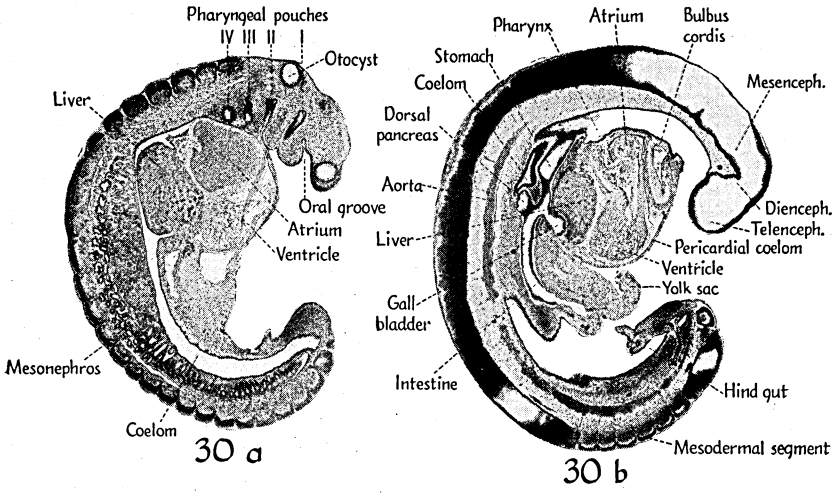
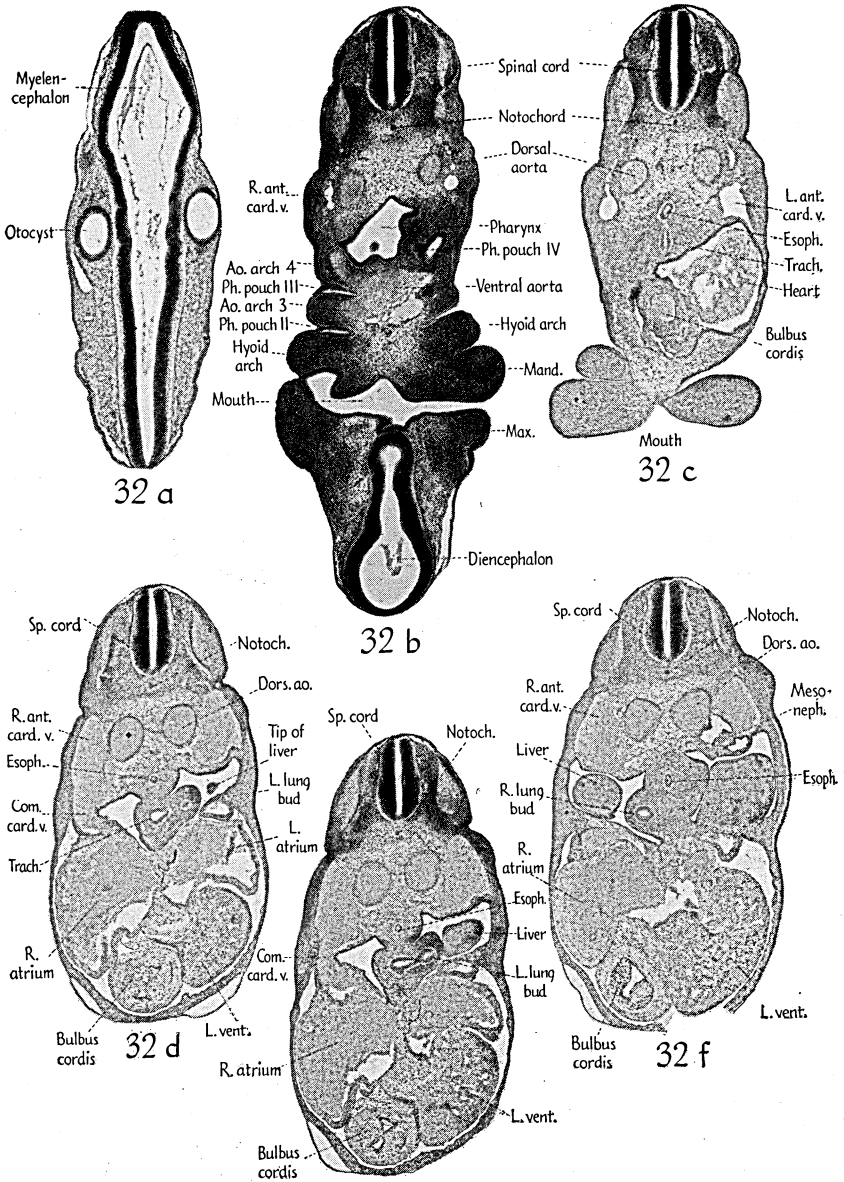


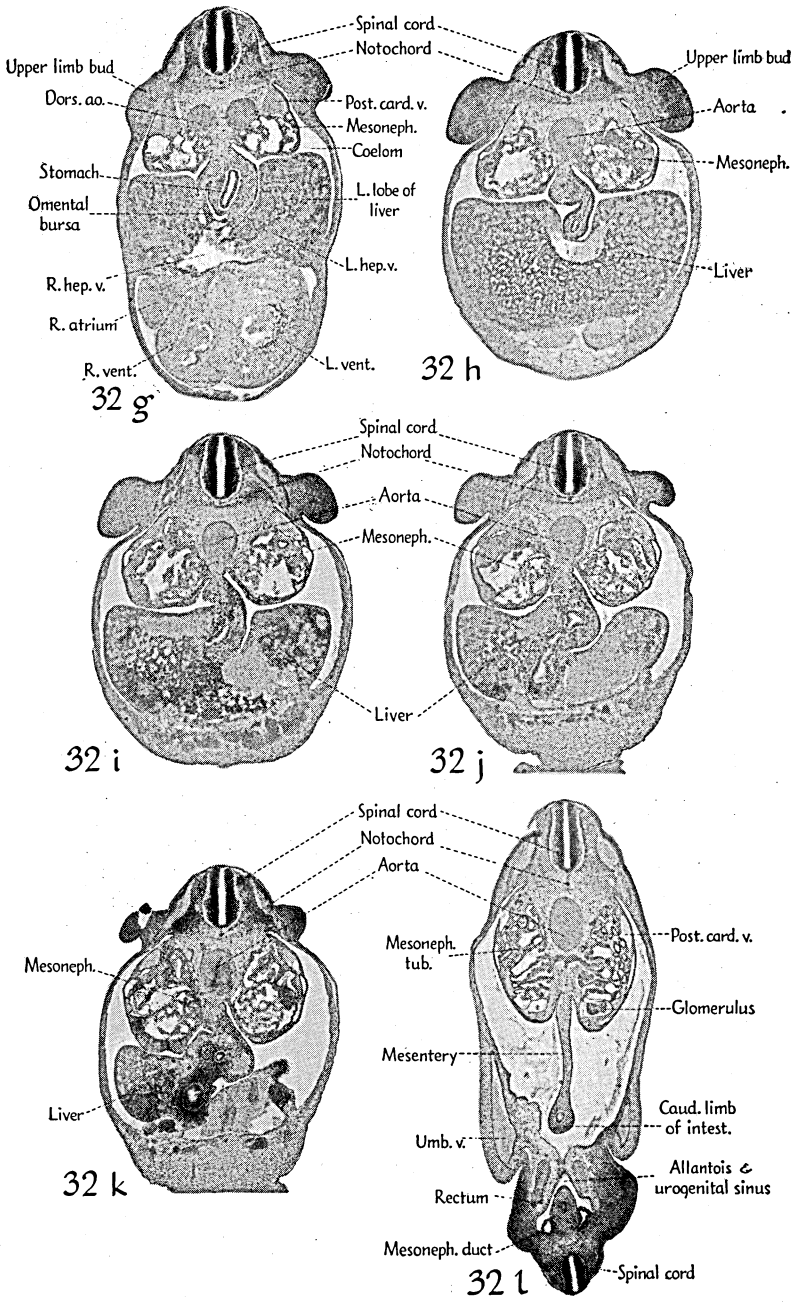
FIG. 30a, 26 DAYS ±, ×15; FIG. 30b, 26 DAYS ±, ×15; FIG. 31, 26 DAYS-15 HOURS, ×7.2; FIG. 32, 27 DAYS-14 HOURS, ×6.4

the pharyngeal area. The sections shown in figures 32c, d, e, and f, sections No. 138, 182, 186, and 204, illustrate the structures found in the heart region while figure 32g, section No. 218, shows the stomach structure at this age. The next group (Figs. 32h, i, j, and k), sections No. 285, 301, 323, and 332, are representative sections of the upper limb bud area. The last photomicrograph (Fig. 32L), section No. 410, represents the structures to be found in the cloacal region.

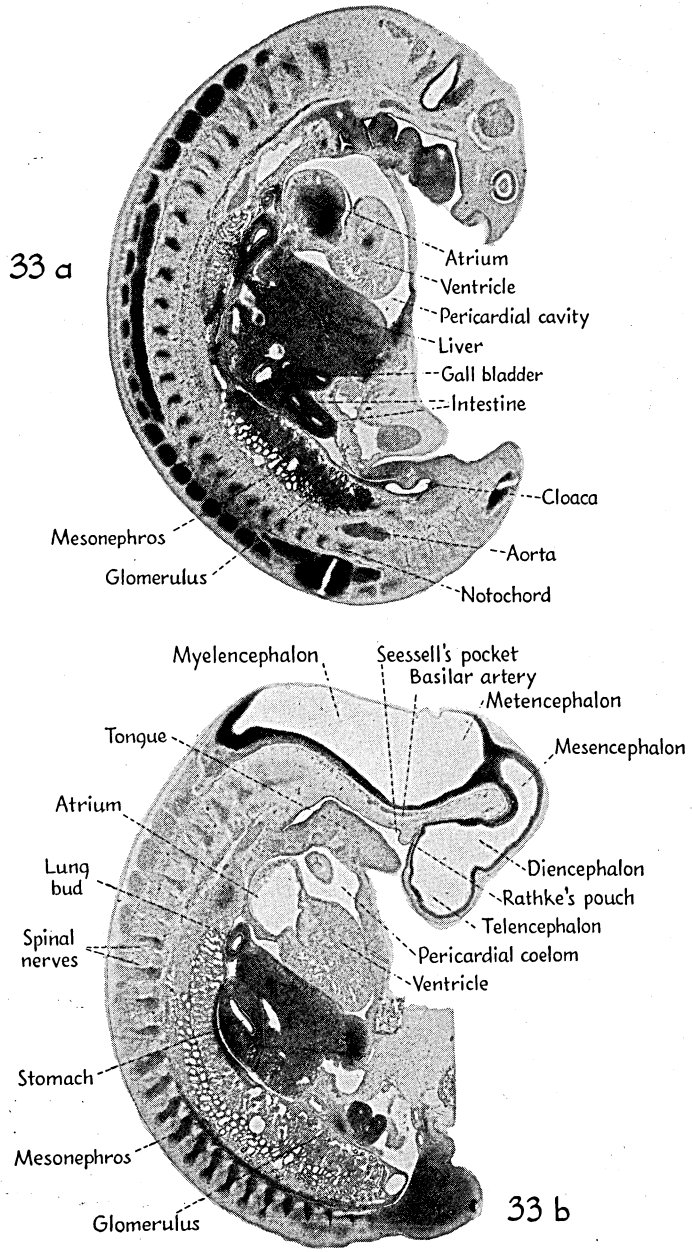
A slaughterhouse specimen of approximately 29 days was sectioned longitudinally and two sections are shown in figures 33a and b. Both are sagittal sections and are presented to assist in the orientation of the structures illustrated in the figure 32a-32L series.



FIGS. 32a-32c, ×19; FIGS. 32d-32f, ×17



FIGS. 32g-32L, ×16



FIGS. 33a-33b. 29 DAYS ±, ×10

The embryo illustrated in figure 34 was 30 days-11 hours old. The crown-rump and contour lengths were 1.113 cm. and 3.159 cm., respectively. In comparison with the 27 day specimen, the facial features including the nasal pits were further differentiated. The cephalic flexure was more prominent and both the cervical and caudal flexures had appeared.

Figure 35 is the picture of a 32 day-14 hour embryo whose crown-rump length was 1.19 cm. and contour length was 3.445 cm. Externally, the dorsal portions of the body are rapidly differentiating, and the vertebrae are becoming more highly organized and are enlarging in size; the limb buds are not only growing but also undergoing more regional specialization. All of these changes assist in producing the body form characteristic of the late embryonic and early fetal stages.

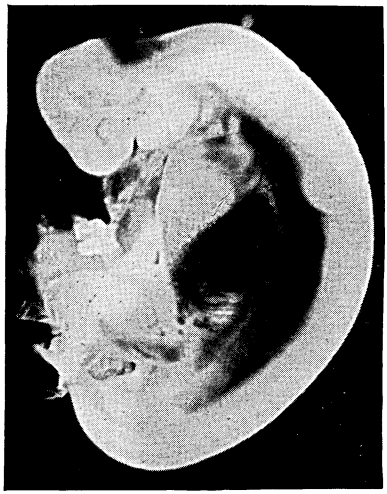
Four hundred and twenty-five sections were secured from the embryo in figure 35. Figure 35a, section No. 84, illustrates the structures in the region of the dien- and meten-cephalon and the otocyst. The next sections, No. 110, 127, 140, and 151 (Figs. 35b, c, d, and e), were taken from the pharyngeal and gill arch areas while figures 35f and g, sections No. 176 and 231, show the structures to be found in the heart and limb bud regions.

A 37 day-3 hour old embryo is shown in figure 36. The specimen weighed 0.96 gm. and the crown-rump and contour lengths were 1.826 cm. and 4.306 cm., respectively. In this embryo, the facial features were clearly shown. The body features of interest were the increased emphasis of the points of body flexion as the result of elongation and straightening of the dorsal portion of the body and the further definition of both the liver prominence and the ribs.

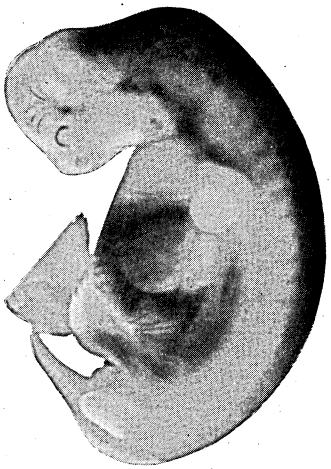
The sections of the above 37-day-old embryo caudal to the liver were not suitable for study. The sections to be presented of the more caudal regions were secured from an embryo (Fig. 37) whose estimated age was 37 days and whose crown-rump length was 1.837 cm. and weight was 0.88 gm. Complete serial sections cephalic to the heart were not retained from the slaughterhouse specimen and as a result all the section numbers for this specimen will be based from the last, most caudal, section rather than the first, most cephalic, section as in the case of all the other embryos.

An anomalous neural tube was found in the slaughterhouse specimen (Fig. 37). The rest of the organs and tissues appeared normal and the malformation may be regarded as a structure of interest rather than as a cause for discarding the embryo.

Because these two embryos (Figs. 36 and 37) are of essentially



34



35

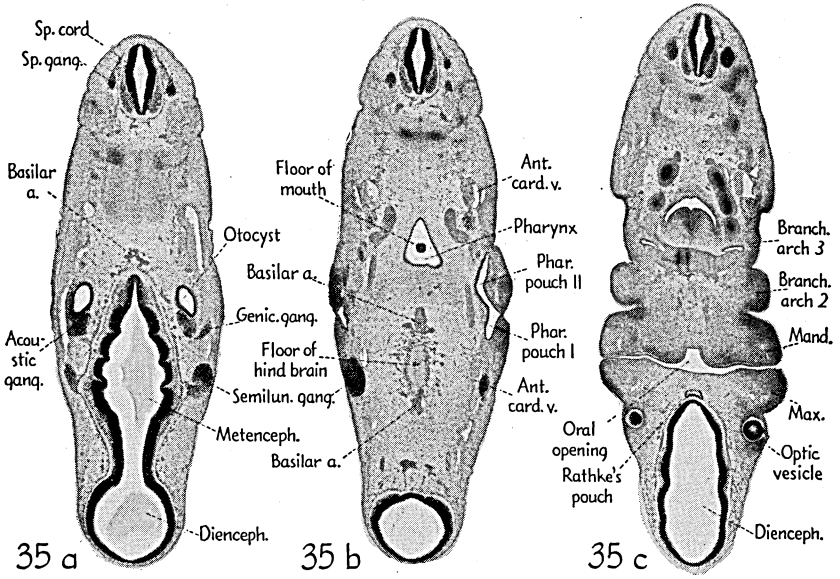
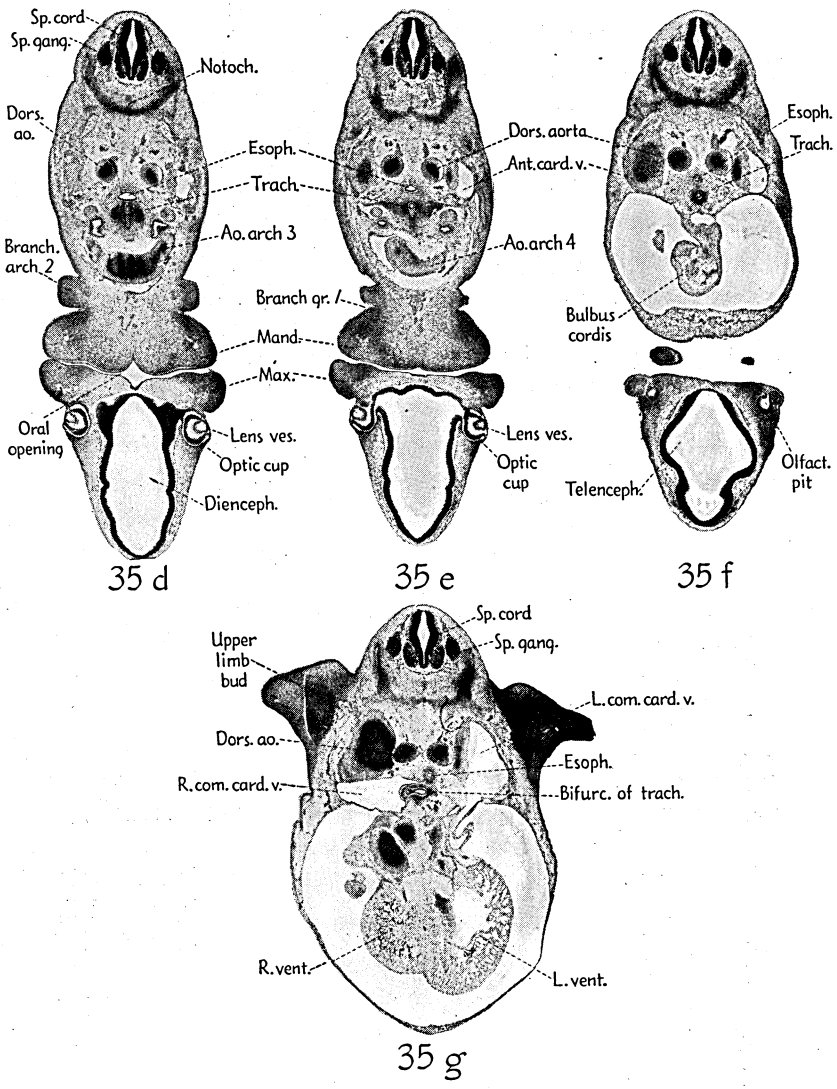
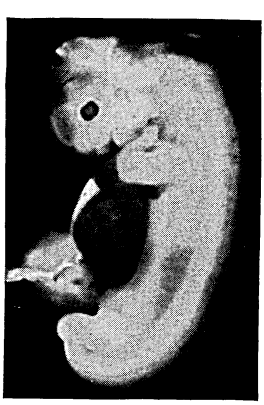


FIG. 34, 30 DAYS-11 HOURS, ×4.9; FIG. 35, 32 DAYS-14 HOURS, ×4.3; FIGS. 35a-35c, ×10.8



FIGS. 35d-35g, ×10.8



36

37

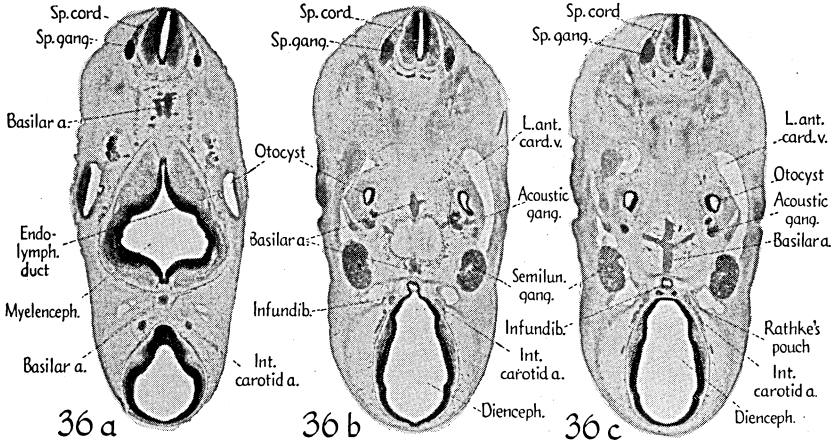
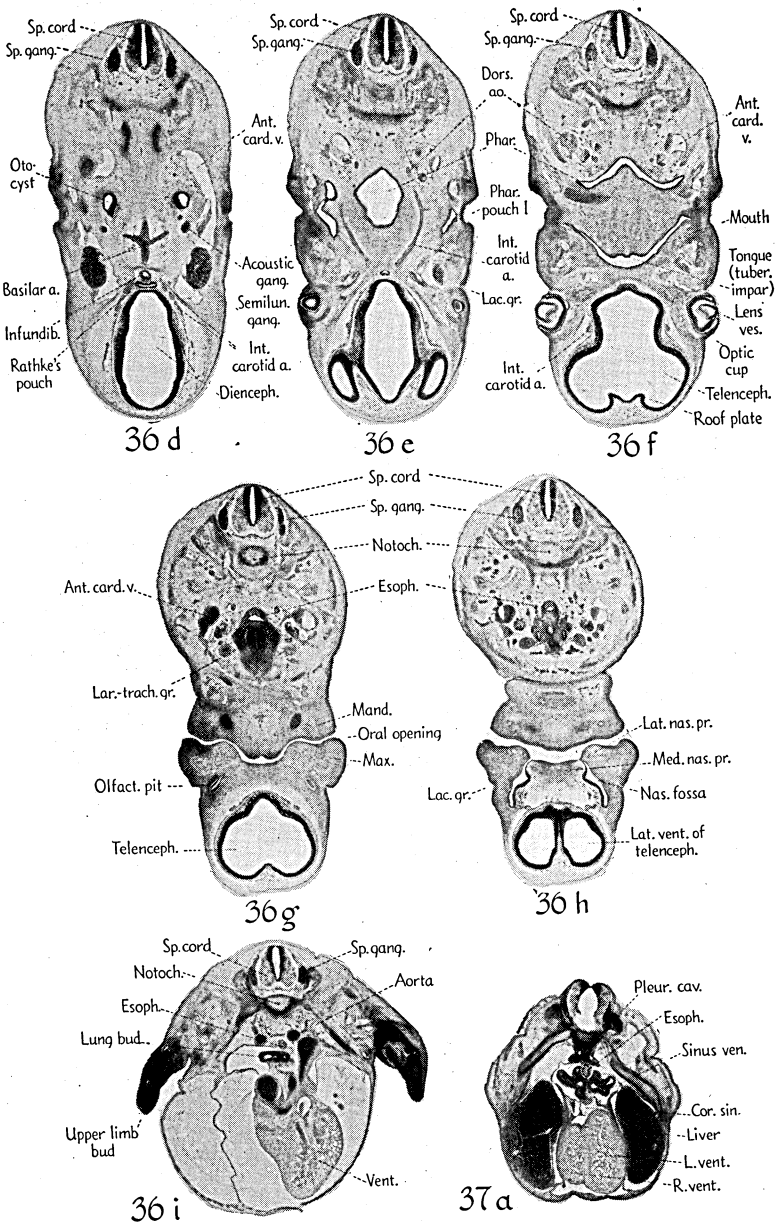
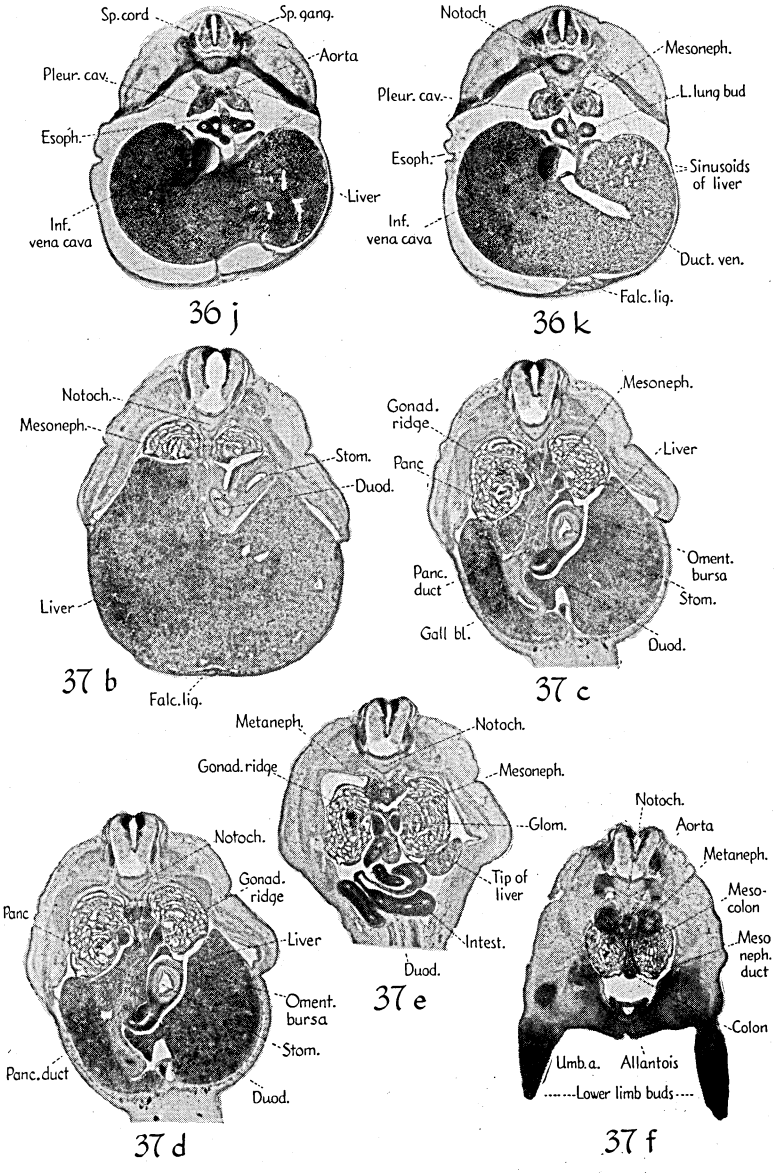


FIG. 36, 37 DAYS-3 HOURS, ×2.8; FIG. 37, 37 DAYS ±, ×3; FIGS. 36a-36c, ×7.8

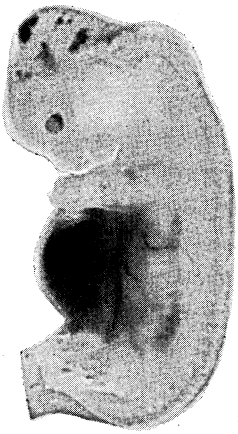
the same structure and neither series of sections is complete, the discussion of the sections coincides. Figures 36a, b, c, and d, sections No. 112, 152, 157, and 159, depict the arrangement of structures in the region of the diencephalon and otocyst. Sections No. 175, 193, 233, and 246 shown in figures 36e, f, g, and h were secured from the optic vesicle and pharyngeal regions. Figure 36i, section No. 354, shows the structures present in the region of the heart and upper limb buds. Extensive tissue condensation may be noted in the areas of future skeletal development both in the limb buds and in the loci of the vertebrae and ribs. The latter is especially true in figure 37a. (Figure 37a, section No. 285, was similar to section No. 370 of the embryo in figure 36, and figure 37b, section No. 214, was from an area similar to section



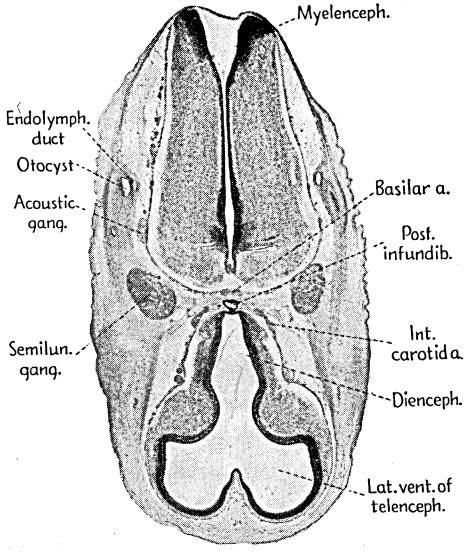
FIGS. 36d-36f, ×6.5; FIGS. 36g-36h, ×6.2; FIG. 36i, ×5.2; FIG. 37a, ×7.3



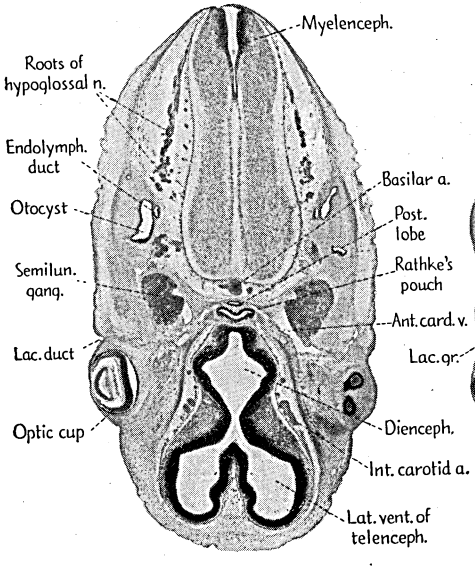
FIGS. 36j-36k, ×5.4; FIGS. 37b-37e, ×7.5; FIG. 37f, ×8.3



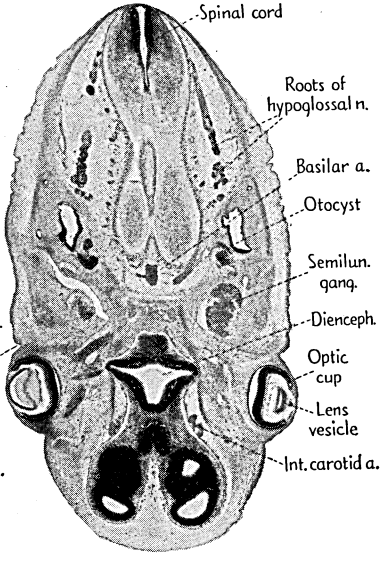
38



38 a

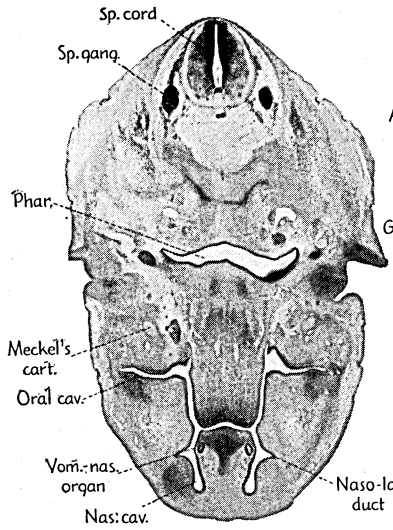


38 b

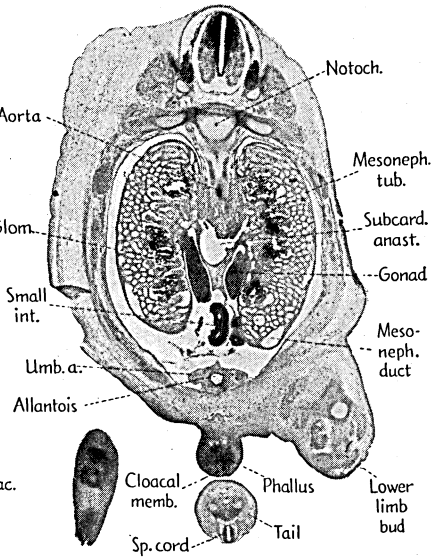


38 c

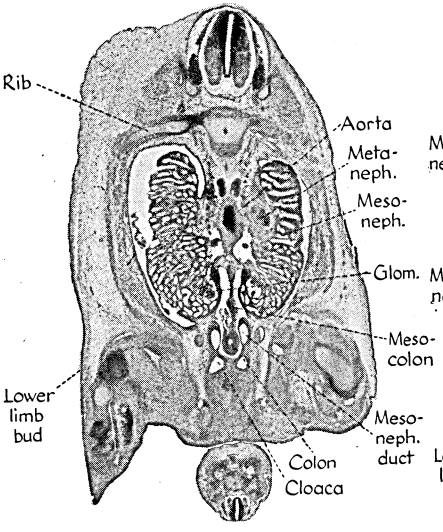
FIG. 38. 40 DAYS-2 HOURS, ×2.4; FIGS. 38a-38c, ×8.6



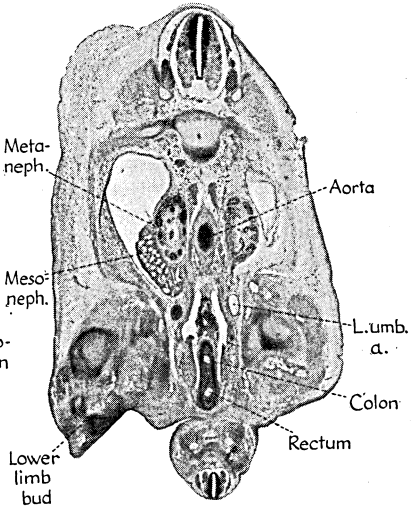
38 d



38 e



38 f



38 g

FIG. 38d, ×8.6; FIGS. 38e-38g, ×7.7

No. 403 of the embryo of figure 36.) Figures 37a, 36j and k, 37b, c, d, and e, sections No. 37-285, 36-380 and 36-390, 37-214, 37-175, 37-172, and 37-146, illustrate the structures to be found at various levels in the liver region. Section No. 101 (Fig. 37f) was secured from the lower limb bud area and shows both the mesonephros and metanephros.

The last of the specimens to be considered in the embryonic series was the 40 day-2 hour old individual shown in figure 38. Its crown-rump length was 2.28 cm. and its contour length was 5.0 cm. Little change in body form was noted when the 37 and 40 day specimens were compared; however, the cervical flexure was not as conspicuous in the older specimen. This was partially due to the increase in size of the cephalic prominence. A total of 760 sections were secured from the 40 day embryo. Sections No. 206, 230, and 238 (Figs. 38a, b, and c) were taken from various levels of the telencephalon and the latter two pass through the region of the optic cup. Section No. 297 (Fig. 38d) was secured from the oral-pharyngeal regions. The last series illustrate the organs associated with portions of the mesonephros. Figure 38e, section No. 587, indicates the extent of gonadal development at this age while figures 38f and g, sections No. 604 and 617, show the development of the metanephros at those two levels.

Fetal Stages

The specimens shown in figures 39, 40, 41, and 42 were 45 days-15 hours, 49 days-13 hours, 54 days-15 hours, and 59 days-16 hours old, respectively, and illustrate the changes in body form which took place during that period. The alterations in the head and neck regions were: the reduction in size of the cephalic prominence, a recession of the cervical flexure, the further formation of facial features, the covering of the eyes by the lids, the elongation of the neck, and a rotation of 90° in the direction of the longitudinal axis of the head in relation to the body axis.

The changes in the abdominal region were mainly the reduction in size of the liver prominence and an extension of the body wall to the umbilicus. The ribs, although outlined in the 37 day embryo (Fig. 36) were becoming quite prominent and some ossification of the structures had occurred.

The appendages likewise underwent a change from the short, thick limbs of the embryo to the slender, more elongated structures of the fetus and post partum individual. Simultaneously, the precosity in development of the front legs was reduced and the rear limbs more nearly equaled the front, not only in length

but also in degree of differentiation. Some of these fundamental changes in body proportion continued to take place up to 70 days of age (Fig. 43). The alterations in body form from 70 days until birth, although definite, were not radical. These alterations may best be observed by a study of figures 44-59, inclusive.

The differences in genetic background of the parents were responsible for slight differences in skin and hair pigmentation, body proportions, and fetal size at a given age but were not essential factors in determining the general trend of body changes during the fetal period.

A few features in addition to body measurements which might assist in the determination of the age of a specimen were noted. The first hair follicles were observed in the 90 day specimen (Fig. 44). Twenty days later a slight pigmentation of the follicles was to be seen. A few hairs were formed in the region of the eye and muzzle at 150 days (Fig. 50), but the hair coat did not cover the body until approximately 230 days (Fig. 56). The horn pits were first discernible in the 100 day calf fetus (Fig. 46).

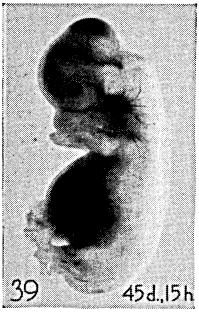
In comparison, a few hairs may be seen about the eye and muzzle of the sheep at 90 days and the body is covered with hair at 116 days. In body development, the 140 day bovine fetus (Fig. 49) is comparable to the 104 day sheep fetus. At these ages, the species of the fetuses can be easily identified.

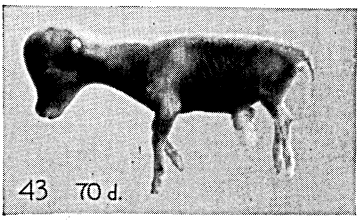
X-ray Studies

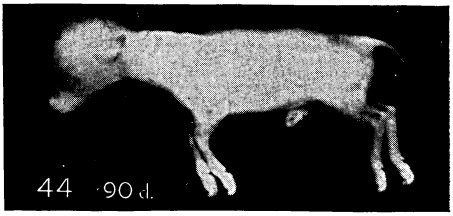
The deposition of sufficient bone substance to be detected by X-ray study occurs early in the fetal period. This early deposition is general, that is, it takes place in both the axial and appendicular portions and is not limited to either cartilage or membrane bones. The series of X-ray pictures are presented to indicate not only the amount of bone development at different ages but also the relative rate of development.

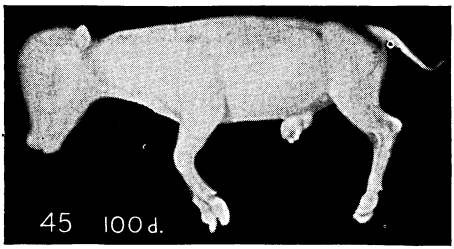
Extensive ossification was present in the 59 day fetus. The X-ray negative was too faint to be included in the present series but the following amount of bone formation could be noted: there was some development of the bones of both the upper and lower jaw as well as in the regions of the frontal bone and cranial cavity; while the vertebrae did not show, all 13 pairs of ribs could be seen; the humerus, ulna, and radius of both front legs were present; and the femur and tibia were visible in the hind legs. No other structures were indicated.

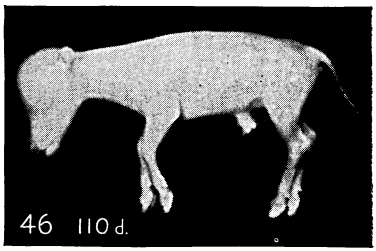
Practically all of the bones of the axial group show some ossification at 70 days (Fig. 43[1,2]). Development had taken place

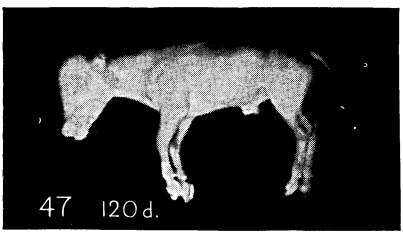


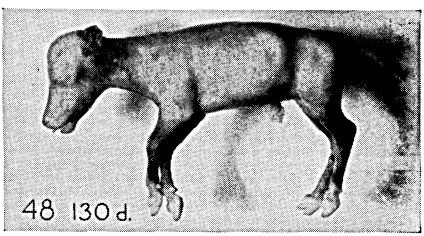


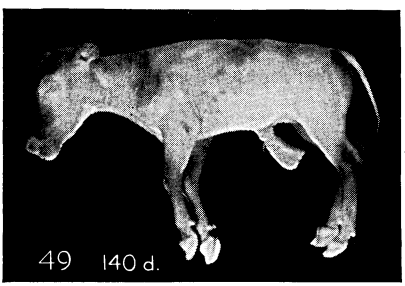












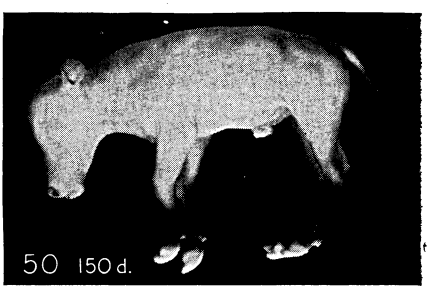


FIG. 39, ×1.1; FIG. 40, ×0.9; FIG. 41, ×0.75; FIG. 42, ×0.5; FIG. 43, ×0.25; FIG. 44, ×0.25; FIG. 45, ×0.26; FIG. 46, ×0.17; FIG. 47, ×0.13; FIG. 48, ×0.13; FIG. 49, ×0.09; FIG. 50, ×0.13

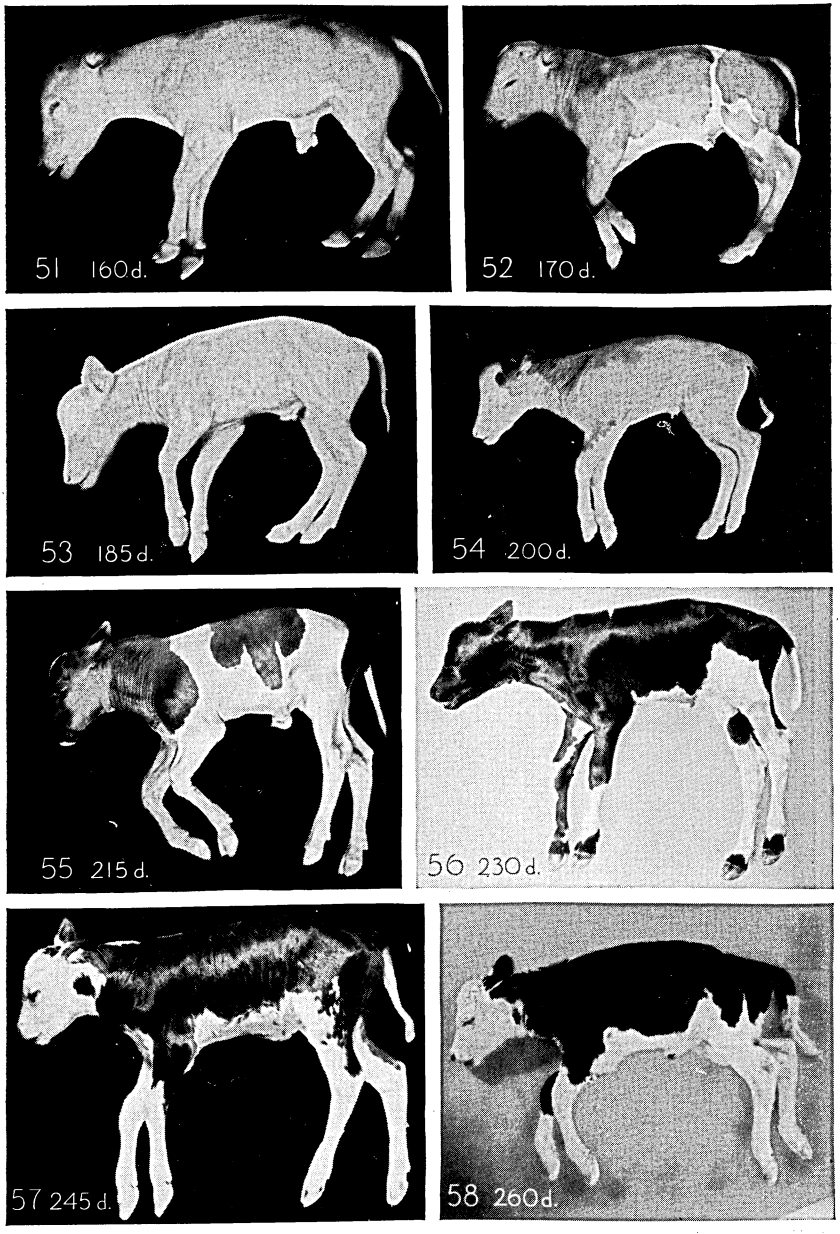


FIG. 51, ×0.12; FIGS. 52-53, ×0.08; FIGS. 54-57, ×0.06; FIG. 58, ×0.05

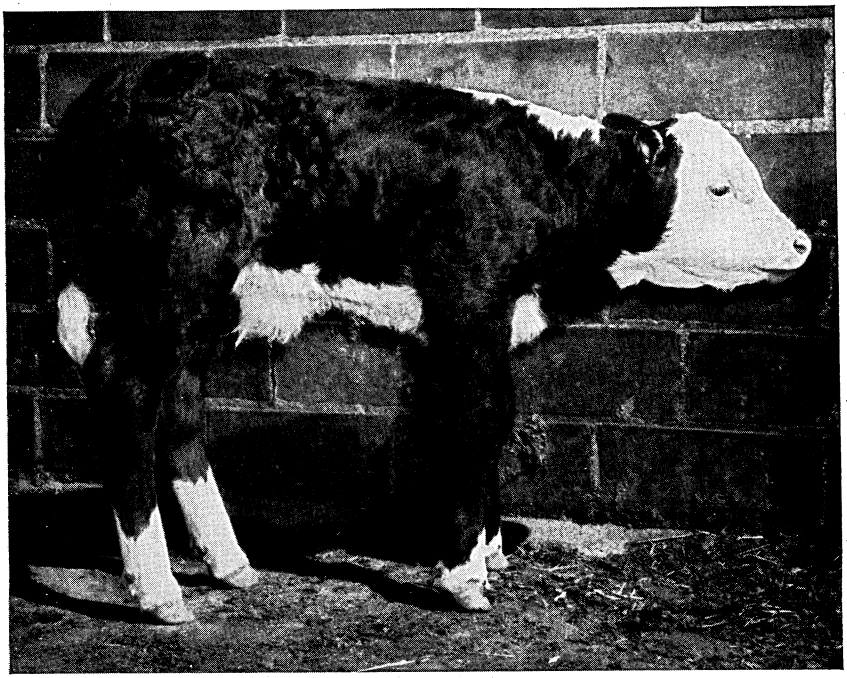


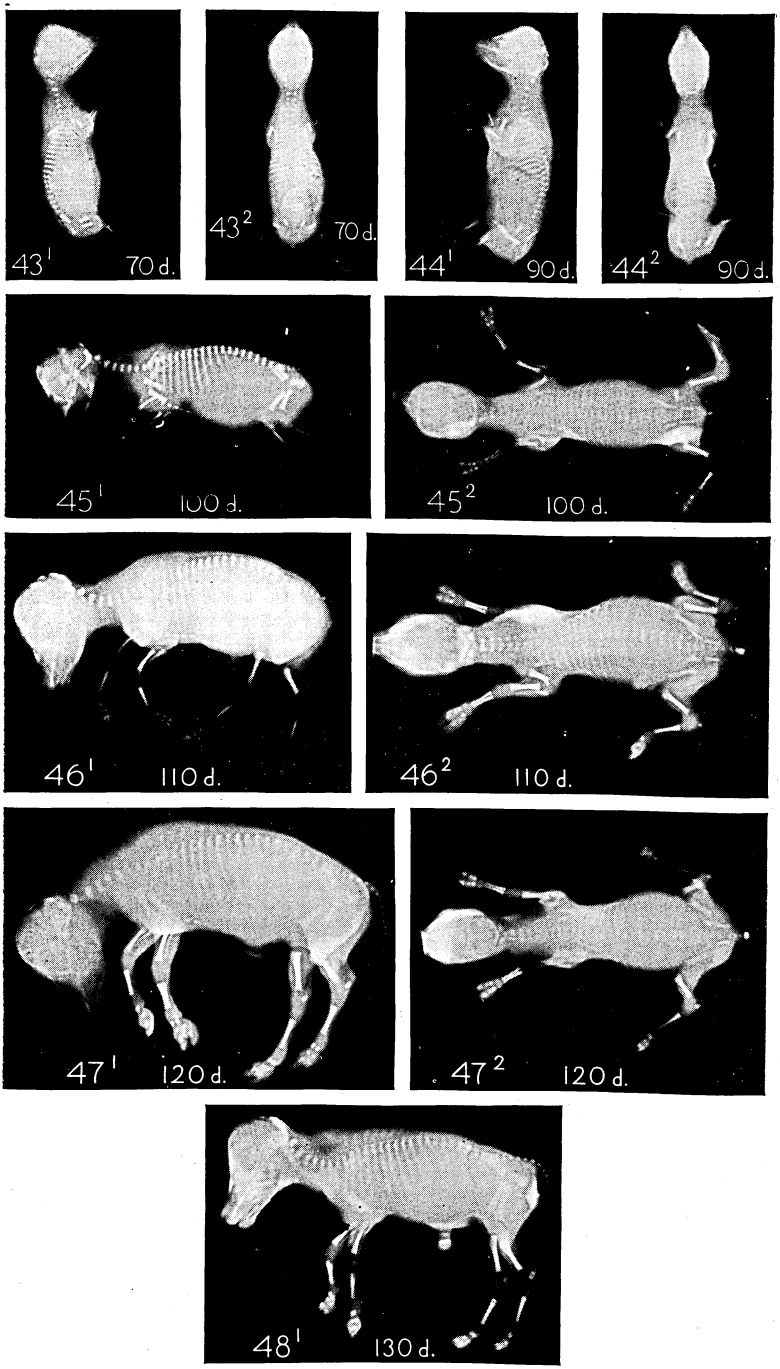
FIG. 59. NEWBORN CALF, ×0.11

in the long bones of the limbs but no deposition was indicated in the tarsal, carpal, or phalangeal bones. The third and fourth metacarpal bones, although separate at 70 days, will later fuse into one structure.

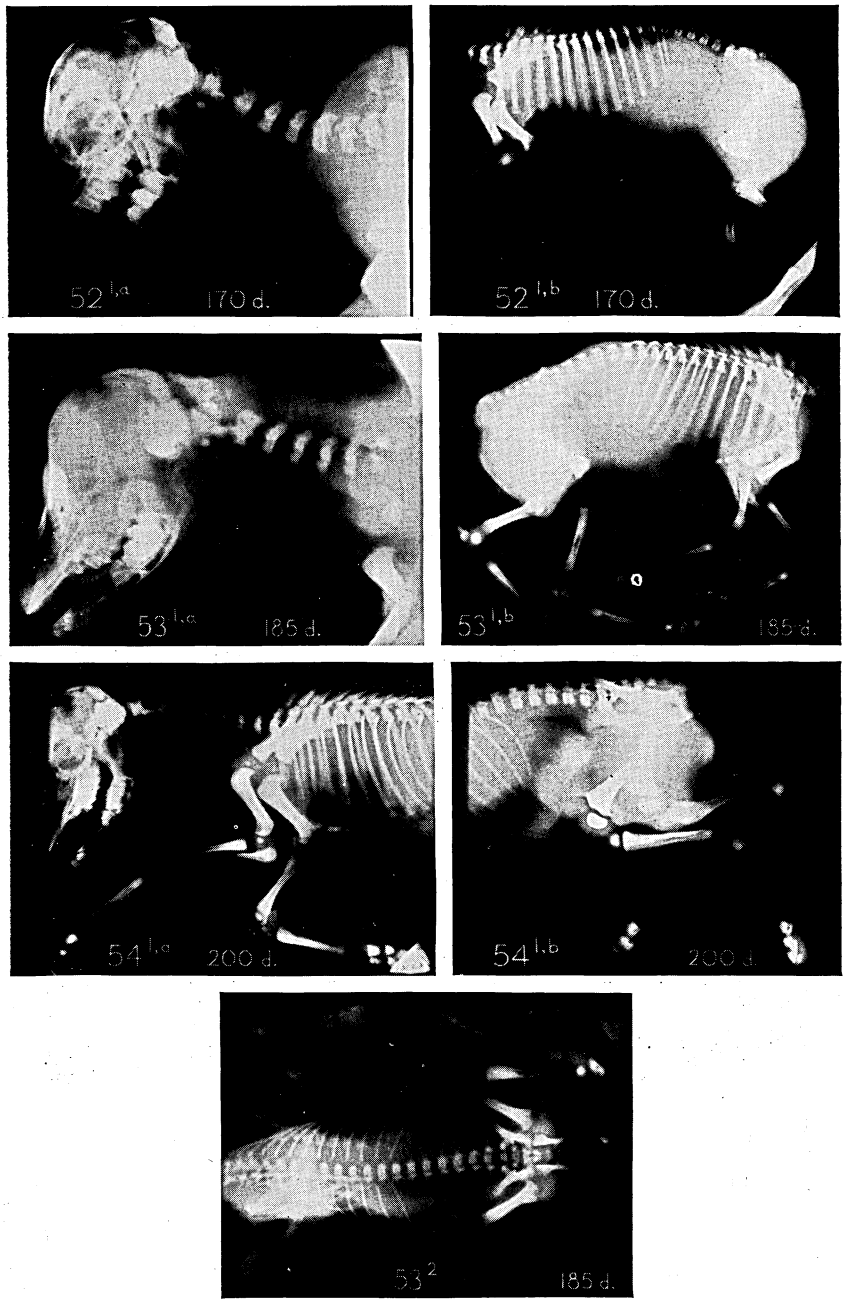
At 90 days of age (Fig. $44^{1,2}$) the sternebrae, phalanges, and coccygeal vertebrae have ossified to some extent. Although many of the long bones are still undifferentiated as to final form, some of them as well as the scapula, ilium, and ischium have started to develop their final shape.

The first short bone to show any ossification was the fibular tarsal bone (Fig. $45^{1,2}$). This occurred at 100 days of age. Little tooth development was evidenced before 110 days of age (Fig. $46^{1,2}$).

Figures $47^{1,2}$, 48^{1}, $52^{1a,b,2}$, and $54^{1a,b}$ illustrate the bone development at 120, 130, 170, 185, and 200 days, respectively. Further ossification of the tarsal bones was shown at 185 days, and at 200 days the carpal and patella bones were visible. No development of the splanchnic skeleton was shown in these pictures; however, these bones are ossified to some extent at birth.



FIGS. 43¹-48¹. X-RAY STUDIES AT VARIOUS STAGES OF THE FETUS



FIGS. 52^{1a}-53^{2}. X-RAY STUDIES AT VARIOUS STAGES OF THE FETUS

PRESENTATION OF DATA

The data in table 1 indicate that the bovine ovum is essentially the same size as that of other mammalian species. A study of figures 4-12 and the measurements of the egg diameters demonstrate that the bovine ovum, like that of the sheep (Clark [4]), does not change appreciably in size prior to the loss of the zona pellucida. After the zona is shed, the blastula remains more or less spherical but increases in diameter until the time of attachment.

Measurements of embryo and fetal specimens are given in tables 2 and 3, respectively. Relative growth in weight was most rapid during the embryonic period. This fact was not demonstrated when the data were plotted on coordinate paper (Fig. 60) but was brought out clearly when the same data were plotted on arith-log paper (Fig. 61). Only slight deviations were found in the curves due to individual variations. When the length of the specimens was plotted against age on both coordinate and arith-log paper (Figs. 62 and 63, respectively), the data indicated a rather gradual change in the growth rate throughout the late

Table 1. Comparative Measurements of Ova

Form	Investigator	Diameter of zonal cavity	Thickness of zona
		mm.	mm.
Cow	(Own data)	0.1448 (0.1355-0.1577)	0.01209 (0.010-0.0153)
Cow	Hartman et al. (10)	0.135-0.140	0.012-0.015
Sheep	Allen et al. (1)	0.125-0.167 (outside diameters)	0.009-0.012
Sheep	Clark (4)	0.147 (0.135-0.160)	0.014 (0.011-0.016)
Pig	Heuser and Streeter (11)	0.130	0.015
Rabbit	Gregory (7)	0.128 (0.110-0.146)	0.019 (0.011-0.023)
Guinea pig	Squier (14)	0.095 (0.087-0.107)	0.012 (0.009-0.0149)

Table 2. Measurements of Bovine Embryos by Age

Age		Contour length	Greatest length	Crown-rump length	Weight
days	hours	cm.	cm.	cm.	gm.
19	14	.302	.235	.....	.....
22	16	.638	.518	.....	.....
24	16	.974	.371	.313	.....
26	2	1.434	.420	.305	.....
26	16	1.788	.558	.358	.....
27	14	2.595	.973	.826	.090
30	11	3.159	1.200	1.113	.280
32	14	3.445	1.275	1.190	.350
37	3	4.306	1.826	1.826	.960
40	2	5.000	2.280	2.280	1.553

Table 3. Measurements of Bovine Fetuses by Age

Age of Fetus	Weight	Forehead-Rump Length	Shoulder Point to Pin Bone	Chest Circumference	Abdomen Circumference	Foreleg Circumference	Hind Leg Circumference	Horizontal Head Circumference	Head Length	Head Breadth	Face Height, Total	Face Height, Upper	Face Breadth	Forearm Length	Hock to Hoof Point	Tail Length
		cm. Crown rump														
days	gm.	rump	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
45	2.77	3.08	1.6	3.2	4.2	.....	.....	3.2	.5	.825	.....	.....	.78	.475	.45	.....
50	4.94	3.85	2.3	3.7	4.5	0.6	.....	3.4	.6	.850	.65	.....	.90	.500	.60	.75
55	5.62	4.67	2.55	4.3	4.7	0.80	.....	.....	.....	1.075	.73	.....	.90	.675	.70	.85
60	13.78	6.60	3.65	5.35	6.0	0.85	.....	5.4	1.15	1.450	.80	.....	1.10	1.15	1.35	1.95
70	37.25	9.40	5.5	7.40	8.0	1.10	.90	8.0	3.3	2.0	1.30	0.80	1.20	1.90	2.00	2.20
80	.....	.....	.....	.....	.....	1.20	.90	9.9	3.6	2.8	1.30	0.90	1.60	1.90	2.50	2.80
		Forehead														
90	159.8	16.4	10.7	11.5	12.2	1.50	1.50	11.2	5.0	3.3	1.90	1.10	1.80	2.70	3.40	4.00
100	317.2	18.8	12.2	14.0	15.3	2.10	2.10	14.2	6.0	3.9	2.30	1.50	2.30	3.30	5.50	5.20
110	550	24.0	15.8	17.6	19.2	2.50	2.50	17.2	7.5	4.3	2.90	2.00	2.40	4.00	5.60	6.00
120	820	27.1	18.0	20.1	22.0	2.70	2.70	19.0	8.4	5.0	3.80	2.60	2.90	5.00	6.80	7.60
130	1390	31.2	21.4	22.6	25.2	2.90	3.40	20.4	9.7	5.4	4.50	3.40	2.90	6.00	8.50	9.50
140	1807	32.6	21.8	27.0	28.5	4.20	3.60	23.5	11.0	6.1	5.10	3.90	3.60	7.20	10.00	9.00
150	2746	36.8	24.6	31.4	34.2	4.50	4.10	26.7	12.8	6.8	5.00	3.10	4.60	8.00	10.50	10.30
160	3562	43.7	29.1	32.0	35.2	5.00	4.70	27.8	13.2	7.5	6.00	4.40	4.30	9.10	12.30	11.80
170	7144	48.5	35.0	41.8	43.0	6.50	6.30	33.0	15.0	8.5	7.00	5.20	5.70	11.00	16.00	17.50
185	6685	54.0	36.0	39.4	43.8	6.60	6.50	33.4	16.6	8.3	6.90	5.40	5.50	13.20	17.20	17.20
200	10433	58.5	40.6	48.3	50.5	6.90	8.00	36.7	18.2	9.4	8.10	4.80	5.70	18.50	21.80	23.20
215	16102	70.0	45.5	53.3	56.5	9.40	10.10	42.3	21.0	10.4	10.30	6.60	5.60	20.00	27.00	24.00
230	18144	73.0	56.0	55.0	57.3	8.60	9.0	41.2	18.5	10.2	9.10	7.00	7.20	20.00	28.50	28.00
245	26988	82.0	58.0	63.5	67.0	9.50	9.5	44.0	21.0	11.5	9.50	7.00	7.50	21.00	30.00	28.00
260	31298	87.0	63.0	70.0	71.0	10.00	10.5	46.0	23.0	11.5	11.40	8.00	7.00	23.00	32.00	34.00

embryonic and fetal periods. The graph in figure 65 showed that a more rapid gain in length in proportion to weight took place during the late embryonic and early fetal stages. The greatest effect of individual variation was found when chest circumference was plotted against age (Fig. 64). For some reason, the individual effect was not as great before 150 days as afterward; however, the variation due to individual

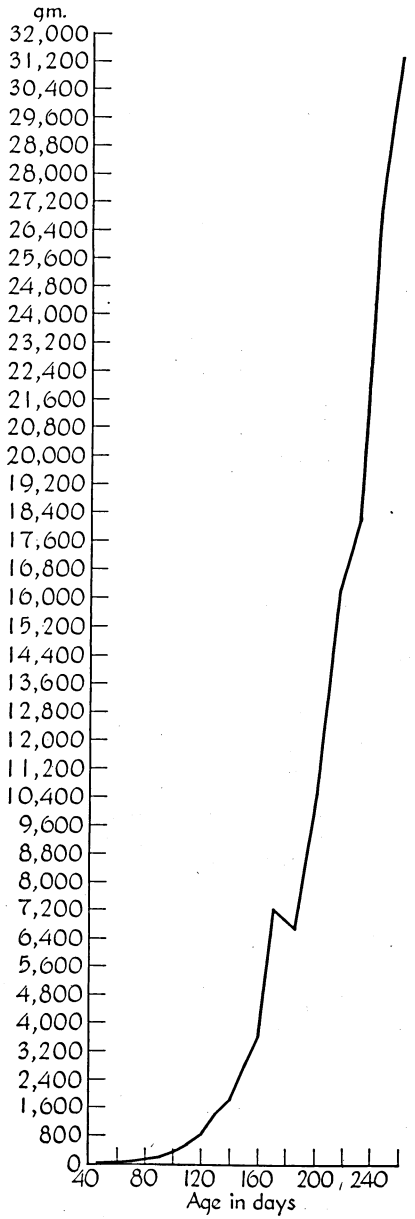


FIG. 60. GROWTH OF THE BOVINE EMBRYO AND FETUS. WEIGHT ON AGE PLOTTED ON COORDINATE PAPER (CONTRAST WITH FIG. 61)

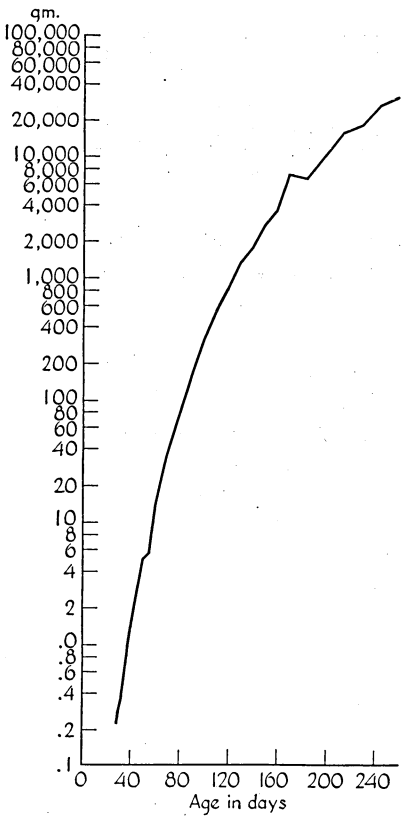


FIG. 61. GROWTH OF THE BOVINE EMBRYO AND FETUS. WEIGHT ON AGE PLOTTED ON ARITH-LOG PAPER (CONTRAST WITH FIG. 60)

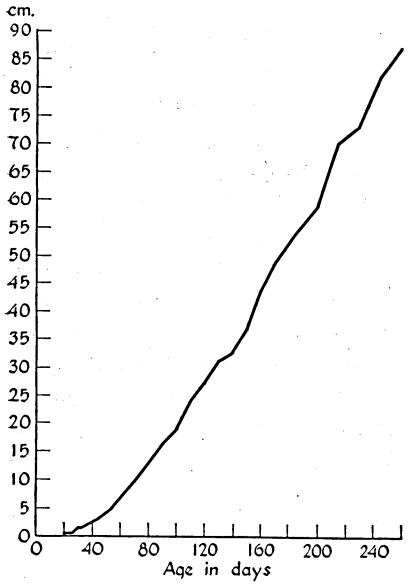


FIG. 62. GROWTH OF THE BOVINE EMBRYO AND FETUS. LENGTH ON AGE PLOTTED ON COORDINATE PAPER (CONTRAST WITH FIG. 63)

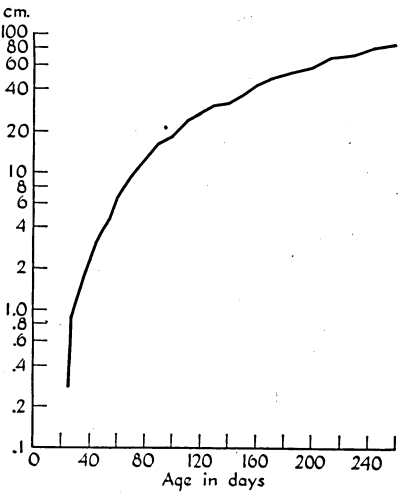


FIG. 63. GROWTH OF THE BOVINE EMBRYO AND FETUS. LENGTH ON AGE PLOTTED ON ARITH-LOG PAPER (CONTRAST WITH FIG. 62)

effect did not apparently change the general trend of the curve.

The ratios of body parts to forehead-rump length are presented in table 4. The weight of the specimens in proportion to their length increased stead-

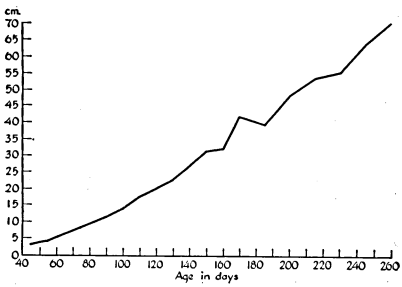


FIG. 64. GROWTH OF THE BOVINE EMBRYO AND FETUS. CHEST CIRCUMFERENCE ON AGE PLOTTED ON COORDINATE PAPER

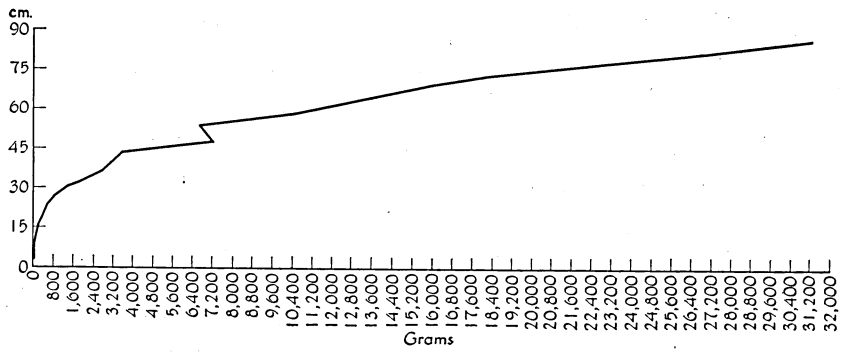


FIG. 65. GROWTH OF THE BOVINE EMBRYO AND FETUS. LENGTH ON WEIGHT PLOTTED ON COORDINATE PAPER

Table 4. Ratio of Various Parts to Forehead-Rump Length

Age of Fetus	Weight	Chest Circumference	Abdomen Circumference	Foreleg Circumference	Horizontal Head Circumference
days	1:	1:	1:	1:	1:
45	1.37	1.19	0.9	.....	1.19
50	.78	1.04	0.86	6.42	1.13
55	.83	1.09	0.99	5.84	.....
60	.48	1.23	1.10	7.77	1.22
70	.25	1.27	1.18	8.55	1.18
90	.10	1.43	1.34	10.93	1.46
100	.059	1.34	1.23	8.95	1.32
110	.044	1.36	1.25	9.60	1.40
120	.033	1.35	1.23	10.04	1.42
130	.022	1.38	1.24	10.76	1.53
140	.018	1.21	1.14	7.76	1.39
150	.013	1.17	1.08	8.18	1.38
160	.012	1.37	1.24	8.74	1.57
170	.0068	1.16	1.13	7.46	1.47
185	.0081	1.37	1.23	8.18	1.62
200	.0056	1.21	1.16	8.48	1.59
215	.0043	1.31	1.24	7.45	1.65
230	.0040	1.33	1.27	8.49	1.77
245	.0030	1.29	1.22	8.63	1.86
260	.0028	1.24	1.23	8.70	1.89

ily throughout the entire period (see also Fig. 65). In contrast, the horizontal head circumference decreased in proportion as the specimen grew older. The chest and abdominal circumferences were both relatively large in the 45-70 day specimens (see table 4). This was undoubtedly due to the extensive liver prominences at those ages. After 100 days these proportions stayed rather constant.

DISCUSSION

The material in this study was secured from one specimen per given age, except in a few cases. Two factors must be taken into consideration when studying the specimens or data. These factors are (1) the normal variation one might expect within a group of specimens secured at the same age and (2) the time interval between specimens.

While some variation is to be expected among specimens of the same age, when the data were plotted the curves were quite smooth except at a few points. This fact would not have been so striking had all of the specimens been from females such as the previously mentioned group of heifers which had had the same care for a considerable time prior to breeding. Many of the specimens, especially in the embryonic and fetal stages, were, however, secured from a heterogeneous group of cows which varied in age, size, breeding, and probably former care. On the other hand, the smoothness of the curves may have been due,

in part, to the effect of the length of the time interval between specimens. The intervals, although relatively short as measured by days and hours, were usually long enough to allow profound changes to take place in the specimen; this was especially true prior to the fetal period. This time effect would, in part, mask the individual variation. In any case, the data, as secured, indicated that prenatal growth was a continuous process and although the relative growth rate was less as the individual grew older, the rate changed gradually and no sudden changes were found to occur.

The time and manner of the effect of breed on the development of the prenatal individual was not ascertained in this study. It would be of interest to know just when the differences in the rate of development take place, for example, between the Holstein-Friesian breed whose mature females weigh 1,250 pounds and whose calves weigh 70-125 pounds at birth and the Jersey breed whose weights are 900 pounds and 40-70 pounds, respectively.

The appearance of an embryo or fetus necessarily reflects the amount of growth and/or differentiation of the various body parts and for that reason is perhaps subject to less error in the estimation of embryonic development than other common measures. The number of blastomeres, the presence or absence of the zona pellucida, the size and shape of the germ disc, the number and amount of differentiation of body parts, and **body shape** are some of the landmarks which can be used to identify different stages of development with comparative accuracy. Thus comparable stages of development can be easily identified in the same or different species regardless of contrast in weight, age, length, or other dimensions.

In those species, such as the rabbit, that ovulate at a rather definite time after coitus, there is very little variation among specimens of a given age, especially in the period of the ovum; consequently, age is a reliable index of development. In those animals that ovulate spontaneously, more variation in the actual development for an estimated age is encountered, particularly in the early stages. This variation could be overcome to a large extent, of course, by ascertaining the exact time of ovulation; however, this is quite difficult in species such as the sheep and pig and not always practical in the cow. Furthermore, the development of a zygote depends not alone on its age, but there are reasons for believing that the development may also be

affected by the quality of the egg itself, the uterine environment, and the genetic constitution of the zygote. The latter may be of greater importance than some of the other factors.

Embryos and fetuses may be of the same or similar weight but be of different ages or be in different stages of development. This fact was found not only in this study but also by Winters and Feuffel (16) in a study of fetal sheep. In addition, the care of the technician will affect the accuracy of weights. The loss of blood from the specimens, the care in drying, and the type of solution to which the specimen is exposed may all be factors affecting the results from one worker to another. Nevertheless, if weight is used along with other measures, it has value in determining the development of a specimen especially if technics of weighing are held constant. The graphs and tables presented in this paper and also Winters' and Feuffel's work may be used as guides; however, larger numbers would have to be secured and breed variations would have to be studied before reliable estimates of development could be made from weight measures.

The contour measurement was a more satisfactory measure of growth from the somite to the fetal stage than either crown-rump length or greatest length. These latter measurements were placed in table 2 because they are usually reported by other investigators and would, therefore, be of more comparative value than contour measurement which to the authors' knowledge has not previously been used. The crown-rump and greatest length measurements have the common failing of varying with the configuration of the embryo rather than with its actual growth or development. This was evident from the data in table 2 which showed that both decreased during the period of 24 and 26 days while the contour measurement indicated that period as the beginning of an era of greater growth which was actually the case.

From the above discussion, it is clear that no one body measurement, either weight or length, when used alone, adequately describes the development of the embryo. While this does not mean that they are not useful in the description of a specimen, it is essential to remember when using these measures that embryos having similar measurements may vary considerably in development; that one embryo may be older than another and still be smaller as measured by crown-rump or greatest length methods; and that weight of tissue is not necessarily an indication of the degree of differentiation of different embryonic tissues.

A study of the specimens presented in this paper indicates

that the prenatal individual undergoes a series of changes in shape. These changes, like growth itself, are continuous and merge one into the other. In addition, the shape of the individual does not undergo retrogression such as was found true for some of the length measures. Because of the inadequacies of measures such as weight, length, and volume for comparing embryos and because the appearance of the specimen is more directly related to differentiation, the authors believe appearance is the most valuable single measure for comparison of prenatal specimens.

SUMMARY AND CONCLUSIONS

1. The prenatal development of the bovine was studied by securing specimens of known ages.

2. Photographs of the specimens, photomicrographs of sections, X-ray pictures of bone formation, and body measurements of the specimens were presented and discussed.

3. The bovine ovum is approximately the same size and is similar in appearance to those of the sheep and pig.

4. The two pronuclei were in the process of joining at 23 hours.

5. A cell containing two blastomeres was found at 50 hours.

6. Six- and eight-celled eggs were recovered at 62 and 64 hours, respectively.

7. Ova complete the tubal journey in approximately four days and in about the 16-cell stage.

8. The blastocoele begins to form at approximately seven days.

9. The zona pellucida was lost from the egg about the eighth day.

10. The bovine trophoblast contains a yellow pigment and is more difficult to recover than the sheep trophoblast.

11. Attachment of the embryo to the uterine wall takes place during the eleventh to twelfth days. The chorion starts elongating at approximately the same time.

12. The process of gastrulation was complete at 13 days.

13. Mesoderm started to form at 14 days.

14. Somites were found at 19 days and all had formed in the 25-day-old embryo.

15. The first gill arch was noted in the 22-day-old specimen; the allantois was also present in the same embryo.

16. The anterior limb buds were present at 25 days of age.

17. Contour length is a more desirable and, at least at certain stages, a more accurate measure of embryonic development than are either the crown-rump or greatest length measurements.

18. Appearance is evidently the most reliable single measure of the development of an individual specimen.

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APPENDIX

Explanation of Abbreviations

A.—artery
Anast.—anastomosis
Ant.—anterior
Ao.—aorta, aortic
Bifurc.—bifurcation
Bl.—bladder
Branch.—branchial
Card.—cardinal
Cart.—cartilage
Caud.—caudal
Cav.—cavity
Ceph.—cephalic
Com.—common
Cor.—coronary
Desc.—descending
Dienceph.—diencephalon
Dors.—dorsal
Duct.—ductus
Duod.—duodenum
Esoph.—esophagus
Falc.—falciform
Gang.—ganglion
Genic.—geniculate
Glom.—glomerulus
Gonad.—gonadal
Gr.—groove
Hep.—hepatic
Inf.—inferior
Infundib.—infundibulum
Int.—internal, intestine
Intest.—intestine
L.—left
Lac.—lacrimal
Lat.—lateral
Lig.—ligament
Lymph.—lymphatic
Mand.—mandible
Max.—maxillary
Med.—median
Memb.—membrane
Mes.—mesodermal
Mesenceph.—mesencephalon
Mesoneph.—mesonephric, mesonephros
Metaneph.—metanephros
Metenceph.—metencephalon
Myelenceph.—myelencephalon
N.—nerve
Nas.—nasal
Notoch.—notochord
Olfact.—olfactory
Oment.—omental
Panc.—pancreas, pancreatic
Ph.—pharyngeal
Phar.—pharynx
Pleur.—pleural
Post.—posterior
Pr.—process
R.—right
Seg.—segment
Semilun.—semilunar
Sin.—sinus
Som.—somite
Sp.—spinal
Stom.—stomach
Subcard.—subcardinal
Telenceph.—telencephalon
Trach.—trachea
Tub.—tubule
Tuber.—tuberculum
Umb.—umbilical
V.—vein
Ven.—venosus
Vent.—ventricle
Ves.—vesicle
Vitell.—vitelline
Vom.—vomer

End